

PAK 5 SCREENING METHODS

RELATED APPLICATIONS

[0001] This application is a divisional of U.S. Application Serial No. 09/688,188 filed October 16, 2000, which is a divisional of U.S. Application Serial No. 09/291,417, filed April 13, 1999, which in turn claims priority to U.S. Provisional Application Serial No. 60/081,784, filed April 14, 1998. This application claims only subject matter disclosed in the parent application and therefore presents no new matter.

[0002] The instant application contains a "lengthy" Sequence Listing which has been submitted via triplicate CD-R in lieu of a printed paper copy, and is hereby incorporated by reference in its entirety. Said CD-R are labeled "CRF", "Copy 1" and "Copy 2", respectively, and each contains only one identical 329 Kb file (38602329.APP).

FIELD OF THE INVENTION

[0003] The present invention relates to novel kinase polypeptides, nucleotide sequences encoding the novel kinase polypeptides, as well as various products and methods useful for the diagnosis and treatment of various kinase-related diseases and conditions.

BACKGROUND OF THE INVENTION

[0004] The following description of the background of the invention is provided to aid in understanding the invention, but is not admitted to be or to describe prior art to the invention.

[0005] Cellular signal transduction is a fundamental mechanism whereby external stimuli that regulate diverse cellular processes are relayed to the interior of cells. One of the key biochemical mechanisms of signal transduction involves the reversible phosphorylation of proteins, which enables regulation of the activity of mature proteins by altering their structure and function.

[0006] The best characterized protein kinases in eukaryotes phosphorylate proteins on the hydroxyl moiety of serine, threonine and tyrosine residues. These kinases largely fall into two groups, those specific for phosphorylating serines and threonines, and those specific for phosphorylating tyrosines. Some kinases, referred to as "dual specificity"

kinases, are able to phosphorylate on tyrosine as well as serine/threonine residues.

[0007] Protein kinases can also be characterized by their location within the cell. Some kinases are transmembrane receptor-type proteins capable of directly altering their catalytic activity in response to the external environment such as the binding of a ligand. Others are non-receptor-type proteins lacking any transmembrane domain. They can be found in a variety of cellular compartments from the inner surface of the cell membrane to the nucleus.

[0008] Many kinases are involved in regulatory cascades wherein their substrates may include other kinases whose activities are regulated by their phosphorylation state. Ultimately the activity of some downstream effector is modulated by phosphorylation resulting from activation of such a pathway.

[0009] Protein kinases are one of the largest families of eukaryotic proteins with several hundred known members. These proteins share a 250-300 amino acid domain that can be subdivided into 12 distinct subdomains that comprise the common catalytic core structure. These conserved protein motifs have recently been exploited using PCR-based cloning strategies leading to a significant expansion of the known kinases.

[0010] Multiple alignment of the sequences in the catalytic domain of protein kinases and subsequent parsimony analysis permits the segregation of related kinases into distinct branches or subfamilies including: tyrosine kinases, cyclic-nucleotide-dependent kinases, calcium/calmodulin kinases, cyclin-dependent kinases and MAP-kinases, serine-threonine kinase receptors, and several other less defined subfamilies.

SUMMARY OF THE INVENTION

[0011] Through the use of a targeted PCR cloning strategy and of a “motif extraction” bioinformatics script, mammalian members of the STE20-kinase family have been identified as part of the present invention. Multiple alignment and parsimony analysis of the catalytic domain of all of these STE20-family members reveals that these proteins cluster into 9 distinct subgroups. Classification in this manner has proven highly accurate not only in predicting motifs present in the remaining non-catalytic portion of each protein, but also in their regulation, substrates, and signaling pathways. The present invention includes the partial or complete sequence of new members of the STE20-family,

their classification, predicted or deduced protein structure, and a strategy for elucidating their biologic and therapeutic relevance.

[0012] Thus, a first aspect of the invention features an isolated, enriched, or purified nucleic acid molecule encoding a kinase polypeptide selected from the group consisting of STLK2, STLK3, STLK4, STLK5, STLK6, STLK7, ZC1, ZC2, ZC3, ZC4, KHS2, SULU1, SULU3, GEK2, PAK4, and PAK5.

[0013] By "isolated" in reference to nucleic acid is meant a polymer of nucleotides conjugated to each other, including DNA and RNA, that is isolated from a natural source or that is synthesized. The isolated nucleic acid of the present invention is unique in the sense that it is not found in a pure or separated state in nature. Use of the term "isolated" indicates that a naturally occurring sequence has been removed from its normal cellular (*i.e.*, chromosomal) environment. Thus, the sequence may be in a cell-free solution or placed in a different cellular environment. The term does not imply that the sequence is the only nucleotide chain present, but that it is essentially free (about 90 - 95% pure at least) of non-nucleotide material naturally associated with it, and thus is distinguished from isolated chromosomes.

[0014] By the use of the term "enriched" in reference to nucleic acid is meant that the specific DNA or RNA sequence constitutes a significantly higher fraction (2 - 5 fold) of the total DNA or RNA present in the cells or solution of interest than in normal or diseased cells or in the cells from which the sequence was taken. This could be caused by a person by preferential reduction in the amount of other DNA or RNA present, or by a preferential increase in the amount of the specific DNA or RNA sequence, or by a combination of the two. However, it should be noted that enriched does not imply that there are no other DNA or RNA sequences present, just that the relative amount of the sequence of interest has been significantly increased. The term "significant" is used to indicate that the level of increase is useful to the person making such an increase, and generally means an increase relative to other nucleic acids of about at least 2 fold, more preferably at least 5 to 10 fold or even more. The term also does not imply that there is no DNA or RNA from other sources. The other source DNA may, for example, comprise DNA from a yeast or bacterial genome, or a cloning vector such as pUC19. This term distinguishes from naturally occurring events, such as viral infection, or tumor type

growths, in which the level of one mRNA may be naturally increased relative to other species of mRNA. That is, the term is meant to cover only those situations in which a person has intervened to elevate the proportion of the desired nucleic acid.

[0015] It is also advantageous for some purposes that a nucleotide sequence be in purified form. The term "purified" in reference to nucleic acid does not require absolute purity (such as a homogeneous preparation). Instead, it represents an indication that the sequence is relatively more pure than in the natural environment (compared to the natural level this level should be at least 2-5 fold greater, *e.g.*, in terms of mg/mL). Individual clones isolated from a cDNA library may be purified to electrophoretic homogeneity. The claimed DNA molecules obtained from these clones could be obtained directly from total DNA or from total RNA. The cDNA clones are not naturally occurring, but rather are preferably obtained via manipulation of a partially purified naturally occurring substance (messenger RNA). The construction of a cDNA library from mRNA involves the creation of a synthetic substance (cDNA) and pure individual cDNA clones can be isolated from the synthetic library by clonal selection of the cells carrying the cDNA library. Thus, the process which includes the construction of a cDNA library from mRNA and isolation of distinct cDNA clones yields an approximately 10^6 -fold purification of the native message. Thus, purification of at least one order of magnitude, preferably two or three orders, and more preferably four or five orders of magnitude is expressly contemplated.

[0016] By a "kinase polypeptide" is meant 32 (preferably 40, more preferably 45, most preferably 55) or more contiguous amino acids set forth in the amino acid sequence of SEQ ID NO:5, SEQ ID NO:6, or SEQ ID NO:7, or the corresponding full-length amino acid sequence; 250 (preferably 255, more preferably 260, most preferably 270) or more contiguous amino acids set forth in the amino acid sequence SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, or SEQ ID NO:105, or the corresponding full-length amino acid sequence; 27 (preferably 30, more preferably 40, most preferably 45) or more contiguous amino acids set forth in the amino acid sequence SEQ ID NO:18; 16 (preferably 20, more preferably 25, most preferably 35) or more contiguous amino acids set forth in the amino acid sequence SEQ ID NO:22, SEQ ID NO:23, SEQ ID NO:24, SEQ ID NO:29, SEQ ID NO:31, or SEQ ID NO:103 or the corresponding full-length amino acid sequence; 6 (preferably 10, more preferably 15, most preferably 25) or more contiguous amino acids

set forth in the amino acid sequence of SEQ ID NO:97 or SEQ ID NO:99, 22 (preferably 30, more preferably 35, most preferably 45) or more contiguous amino acids set forth in the amino acid sequence of SEQ ID NO:101, or the corresponding full-length amino acid sequence; 78 (preferably 80, more preferably 85, most preferably 90) or more contiguous amino acids set forth in the amino acid sequence SEQ ID NO:107 or functional derivatives thereof as described herein. For sequences for which the full-length sequence is not given, the remaining sequences can be determined using methods well-known to those in the art and are intended to be included in the invention. In certain aspects, polypeptides of 100, 200, 300 or more amino acids are preferred. The kinase polypeptide can be encoded by a full-length nucleic acid sequence or any portion of the full-length nucleic acid sequence, so long as a functional activity of the polypeptide is retained, not to include fragments containing only amino acids 1-22 of SEQ ID NO:13 or only amino acids 1-33 of SEQ ID NO:107.

[0017] The amino acid sequence will be substantially similar to the sequence shown in SEQ ID NO:5, SEQ ID NO:6, SEQ ID NO:7, SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, SEQ ID NO:18, SEQ ID NO:22, SEQ ID NO:23, SEQ ID NO:24, SEQ ID NO:29, SEQ ID NO:31, SEQ ID NO:97, SEQ ID NO:99, SEQ ID NO:100, SEQ ID NO:103, SEQ ID NO:105, or SEQ ID NO:107, or the corresponding full-length amino acid sequence, or fragments thereof, not to include fragments consisting only of the amino acid sequences 1-22 of SEQ ID NO:13 or 1-33 of SEQ ID NO:107. A sequence that is substantially similar to the sequence of SEQ ID NO:5, SEQ ID NO:6, SEQ ID NO:7, SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, SEQ ID NO:18, SEQ ID NO:22, SEQ ID NO:23, SEQ ID NO:24, SEQ ID NO:29, SEQ ID NO:31, SEQ ID NO:97, SEQ ID NO:99, SEQ ID NO:101, SEQ ID NO:103, SEQ ID NO:105, or SEQ ID NO:107 will preferably have at least 90% identity (more preferably at least 95% and most preferably 99-100%) to the sequence of SEQ ID NO:5, SEQ ID NO:6, SEQ ID NO:7, SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, SEQ ID NO:18, SEQ ID NO:22, SEQ ID NO:23, SEQ ID NO:24, SEQ ID NO:29, SEQ ID NO:31, SEQ ID NO:97, SEQ ID NO:99, SEQ ID NO:101, SEQ ID NO:103, SEQ ID NO:105, or SEQ ID NO:107.

[0018] By "identity" is meant a property of sequences that measures their similarity or relationship. Identity is measured by dividing the number of identical residues by the

total number of residues and gaps and multiplying the product by 100. "Gaps" are spaces in an alignment that are the result of additions or deletions of amino acids. Thus, two copies of exactly the same sequence have 100% identity, but sequences that are less highly conserved, and have deletions, additions, or replacements, may have a lower degree of identity. Those skilled in the art will recognize that several computer programs are available for determining sequence identity using standard parameters, for example Blast (Altschul, *et al.* (1997) *Nucleic Acids Res.* 25:3389-3402), Blast2 (Altschul, *et al.* (1990) *J. mol. biol.* 215:403-410), and Smith-Waterman (Smith, *et al.* (1981) *J. Mol. Biol.* 147:195-197).

[0019] In preferred embodiments, the invention features isolated, enriched, or purified nucleic acid molecules encoding a kinase polypeptide comprising a nucleotide sequence that: (a) encodes a polypeptide having the amino acid sequence set forth in SEQ ID NO:5, SEQ ID NO:6, SEQ ID NO:7, SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, SEQ ID NO:18, SEQ ID NO:22, SEQ ID NO:23, SEQ ID NO:24, SEQ ID NO:29, SEQ ID NO:31, SEQ ID NO:97, SEQ ID NO:99, SEQ ID NO:101, SEQ ID NO:103, SEQ ID NO:105, or SEQ ID NO:107; (b) is the complement of the nucleotide sequence of (a); (c) hybridizes under highly stringent conditions to the nucleotide molecule of (a) and encodes a naturally occurring kinase polypeptide; (d) encodes a kinase polypeptide having the amino acid sequence of SEQ ID NO:5, SEQ ID NO:6, SEQ ID NO:7, SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, SEQ ID NO:18, SEQ ID NO:22, SEQ ID NO:23, SEQ ID NO:24, SEQ ID NO:29, SEQ ID NO:31, SEQ ID NO:97, SEQ ID NO:99, SEQ ID NO:103, SEQ ID NO:105, or SEQ ID NO:107, except that it lacks one or more, but not all, of the following segments of amino acid residues: 1-21, 22-274, or 275-416 of SEQ ID NO:5, 1-31, 32-308, 309-489 or 490-516 of SEQ ID NO:6, 1-178 or 179-414 of SEQ ID NO:7, 1-22, 23-289, 290-526, 527-640, 641-896, or 897-1239 of SEQ ID NO:13, 1-255, 256-442, 443-626, 627-954, or 955-1297 of SEQ ID NO:14, 1-255, 256-476, 477-680, 681-983, or 984-1326 of SEQ ID NO:15, 1-13, 14-273, 274-346, 347-534, or 535-894 of SEQ ID NO:18, 1-21, 22-277, 278-427, 428-637, 638-751, or 752-898 of SEQ ID NO:22, 1-66, 67-215, 216-425, 426-539, 540-786, or 787-887 of SEQ ID NO:23, 1-25, 26-273, 274-422, 423-632, or 633-748 of SEQ ID NO:24, 1-51, 52-224, 225-393, 394-658, or 659-681 of SEQ ID NO:29, 1-25, 26-281, 284-430, 431-640, 641-754, 755-901, or 902-1001 of SEQ

ID NO:31, 1-10, 11-321, or 322-373 of SEQ ID NO:97, 1-57, 58-369, or 370-418 of SEQ ID NO:99, 1-52, 53-173, 174-307, 308-572, or 573-591 of SEQ ID NO:103, 1-24, 25-289, 290-397, 398-628, 629-872, or 873-1227 of SEQ ID NO:105, or 1-33, 34-294, 295-337, 338-472, 473-724, or 725-968 of SEQ ID NO:107; (e) is the complement of the nucleotide sequence of (d); (f) encodes a polypeptide having the amino acid sequence set forth in SEQ ID NO:5, SEQ ID NO:6, SEQ ID NO:7, SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, SEQ ID NO:18, SEQ ID NO:22, SEQ ID NO:23, SEQ ID NO:24, SEQ ID NO:29, SEQ ID NO:31; SEQ ID NO:97, SEQ ID NO:99, SEQ ID NO:103, SEQ ID NO:105, or SEQ ID NO:107 from amino acid residues 1-21, 22-274, or 275-416 of SEQ ID NO:5, 1-31, 32-308, 309-489, or 490-516 of SEQ ID NO:6, 1-178 or 179-414 of SEQ ID NO:7, 23-289, 290-526, 527-640, 641-896, or 897-1239 of SEQ ID NO:13, 1-255, 256-442, 443-626, 627-954, or 955-1297 of SEQ ID NO:14, 1-255, 256-476, 477-680, 681-983, or 984-1326 of SEQ ID NO:15, 1-13, 14-273, 274-346, 347-534, or 535-894 of SEQ ID NO:18, 1-21, 22-277, 278-427, 428-637, 638-751, or 752-898 of SEQ ID NO:22, 1-66, 67-215, 216-425, 426-539, 540-786, or 787-887 of SEQ ID NO:23, 1-25, 26-273, 274-422, 423-632, or 633-748 of SEQ ID NO:24, 1-51, 52-224, 225-393, 394-658, or 659-681 of SEQ ID NO:29, 1-25, 26-281, 282-430, 431-640, 641-754, 755-901, or 902-1001 of SEQ ID NO:31, 1-10, 11-321, or 322-373 of SEQ ID NO:97, 1-57, 58-369, or 370-418 of SEQ ID NO:99, 1-52, 53-173, 174-307, 308-572, or 573-591 of SEQ ID NO:103, 1-24, 25-289, 290-397, 398-628, 629-872, or 873-1227 of SEQ ID NO:105, or 1-33, 34-294, 295-337, 338-472, 473-724, or 725-968 of SEQ ID NO:107; (g) is the complement of the nucleotide sequence of (f); (h) encodes a polypeptide having the amino acid sequence set forth in SEQ ID NO:5, SEQ ID NO:6, SEQ ID NO:7, SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, SEQ ID NO:18, SEQ ID NO:22, SEQ ID NO:23, SEQ ID NO:24, SEQ ID NO:29, SEQ ID NO:31, SEQ ID NO:97, SEQ ID NO:99, SEQ ID NO:101, SEQ ID NO:103, SEQ ID NO:105, or SEQ ID NO:107, except that it lacks one or more of the domains selected from the group consisting of a N-terminal domain, a catalytic domain, a C-terminal domain, a coiled-coil structure region, a proline-rich region, a spacer region, an insert, and a C-terminal tail; or (i) is the complement of the nucleotide sequence of (h).

[0020] The term "complement" refers to two nucleotides that can form multiple favorable interactions with one another. For example, adenine is complementary to

thymine as they can form two hydrogen bonds. Similarly, guanine and cytosine are complementary since they can form three hydrogen bonds. A nucleotide sequence is the complement of another nucleotide sequence if all of the nucleotides of the first sequence are complementary to all of the nucleotides of the second sequence.

[0021] The term “domain” refers to a region of a polypeptide which contains a particular function. For instance, N-terminal or C-terminal domains of signal transduction proteins can serve functions including, but not limited to, binding molecules that localize the signal transduction molecule to different regions of the cell or binding other signaling molecules directly responsible for propagating a particular cellular signal. Some domains can be expressed separately from the rest of the protein and function by themselves, while others must remain part of the intact protein to retain function. The latter are termed functional regions of proteins and also relate to domains.

[0022] The term “N-terminal domain” refers to the extracatalytic region located between the initiator methionine and the catalytic domain of the protein kinase. The N-terminal domain can be identified following a Smith-Waterman alignment of the protein sequence against the non-redundant protein database to define the N-terminal boundary of the catalytic domain. Depending on its length, the N-terminal domain may or may not play a regulatory role in kinase function. An example of a protein kinase whose N-terminal domain has been shown to play a regulatory role is PAK65, which contains a CRIB motif used for Cdc42 and rac binding (Burbelo, P.D. et al. (1995) J. Biol. Chem. 270, 29071-290740).

[0023] The N-terminal domain spans amino acid residues 1-21 of the sequence set forth in SEQ ID NO:5, amino acid residues 1-31 of the sequence set forth in SEQ ID NO:6, amino acid residues 1-22 of the sequence set forth in SEQ ID NO:13, amino acid residues 1-13 of the sequence set forth in SEQ ID NO:18, amino acid residues 1-21 of the sequence set forth in SEQ ID NO:22, amino acid residues 1-25 of the sequence set forth in SEQ ID NO:24, amino acid residues 1-51 of the sequence set forth in SEQ ID NO:29, amino acid residues 1-25 of the sequence set forth in SEQ ID NO:31, amino acid residues 1-57 of the sequence set forth in SEQ ID NO:99, amino acid residues 1-52 of the sequence set forth in SEQ ID NO:103, amino acid residues 1-24 of the sequence set forth in SEQ ID NO:105, or amino acid residues 1-33 of the sequence set forth in SEQ ID NO:107.

[0024] The term "catalytic domain" refers to a region of the protein kinase that is typically 25-300 amino acids long and is responsible for carrying out the phosphate transfer reaction from a high-energy phosphate donor molecule such as ATP or GTP to itself (autophosphorylation) or to other proteins (exogenous phosphorylation). The catalytic domain of protein kinases is made up of 12 subdomains that contain highly conserved amino acid residues, and are responsible for proper polypeptide folding and for catalysis. The catalytic domain can be identified following a Smith-Waterman alignment of the protein sequence against the non-redundant protein database.

[0025] The catalytic domain spans amino acid residues 22-274 of the sequence set forth in SEQ ID NO:5, residues 32-308 of the sequence set forth in SEQ ID NO:6, residues 1-178 of the sequence set forth in SEQ ID NO:7, residues 23-289 of the sequence set forth in SEQ ID NO:13, residues 1-255 of the sequence set forth in SEQ ID NO:14, residues 1-255 of the sequence set forth in SEQ ID NO:15, residues 14-273 of the sequence set forth in SEQ ID NO:18, residues 22-277 of the sequence set forth in SEQ ID NO:22, residues 1-66 of the sequence set forth in SEQ ID NO:23, residues 26-273 of the sequence set forth in SEQ ID NO:24, residues 394-658 of the sequence set forth in SEQ ID NO:29, residues 26-281 of the sequence set forth in SEQ ID NO:31, residues 1-278 of the sequence set forth in SEQ ID NO:97, residues 58-369 of the sequence set forth in SEQ ID NO:99, residues 1-103 of the sequence set forth in SEQ ID NO:101, residues 308-572 of the sequence set forth in SEQ ID NO:103, residues 25-289 of the sequence set forth in SEQ ID NO:105, or residues 34-294 of the sequence set forth in SEQ ID NO:107.

[0026] The term "catalytic activity", as used herein, defines the rate at which a kinase catalytic domain phosphorylates a substrate. Catalytic activity can be measured, for example, by determining the amount of a substrate converted to a phosphorylated product as a function of time. Catalytic activity can be measured by methods of the invention by holding time constant and determining the concentration of a phosphorylated substrate after a fixed period of time. Phosphorylation of a substrate occurs at the active-site of a protein kinase. The active-site is normally a cavity in which the substrate binds to the protein kinase and is phosphorylated.

[0027] The term "substrate" as used herein refers to a molecule phosphorylated by a kinase of the invention. Kinases phosphorylate substrates on serine/threonine or tyrosine

amino acids. The molecule may be another protein or a polypeptide.

[0028] The term “C-terminal domain” refers to the region located between the catalytic domain or the last (located closest to the C-terminus) functional domain and the carboxy-terminal amino acid residue of the protein kinase. By “functional” domain is meant any region of the polypeptide that may play a regulatory or catalytic role as predicted from amino acid sequence homology to other proteins or by the presence of amino acid sequences that may give rise to specific structural conformations (*i.e.* coiled-coils). The C-terminal domain can be identified by using a Smith-Waterman alignment of the protein sequence against the non-redundant protein database to define the C-terminal boundary of the catalytic domain or of any functional C-terminal extracatalytic domain. Depending on its length and amino acid composition, the C-terminal domain may or may not play a regulatory role in kinase function. An example of a protein kinase whose C-terminal domain may play a regulatory role is PAK3 which contains a heterotrimeric G_β subunit-binding site near its C-terminus (Leeuw, T. et al (1998) Nature, 391, 191-195).

[0029] The C-terminal domain spans amino acid residues 275-416 of the sequence set forth in SEQ ID NO:5, residues 309-489 of the sequence set forth in SEQ ID NO:6, residues 179-414 of the sequence set forth in SEQ ID NO:7, residues 897-1239 of the sequence set forth in SEQ ID NO:13, residues 955-1297 of the sequence set forth in SEQ ID NO:14, residues 984-1326 of the sequence set forth in SEQ ID NO:15, residues 535-894 of the sequence set forth in SEQ ID NO:18, residues 752-898 of the sequence set forth in SEQ ID NO:22, residues 279-330 of the sequence set forth in SEQ ID NO:97, residues 370-418 of the sequence set forth in SEQ ID NO:99, or residues 873-1227 of the sequence set forth in SEQ ID NO:105.

[0030] The term “signal transduction pathway” refers to the molecules that propagate an extracellular signal through the cell membrane to become an intracellular signal. This signal can then stimulate a cellular response. The polypeptide molecules involved in signal transduction processes are typically receptor and non-receptor protein tyrosine kinases, receptor and non-receptor protein phosphatases, SRC homology 2 and 3 domains, phosphotyrosine binding proteins (SRC homology 2 (SH2) and phosphotyrosine binding (PTB and PH) domain containing proteins), proline-rich binding proteins (SH3 domain containing proteins), nucleotide exchange factors, and transcription factors.

[0031] The term "coiled-coil structure region" as used herein, refers to a polypeptide sequence that has a high probability of adopting a coiled-coil structure as predicted by computer algorithms such as COILS (Lupas, A. (1996) *Meth. Enzymology* 266:513-525). Coiled-coils are formed by two or three amphipathic α -helices in parallel. Coiled-coils can bind to coiled-coil domains of other polypeptides resulting in homo- or heterodimers (Lupas, A. (1991) *Science* 252:1162-1164). Coiled-coil-dependent oligomerization has been shown to be necessary for protein function including catalytic activity of serine/threonine kinases (Roe, J. *et al.* (1997) *J. Biol. Chem.* 272:5838-5845).

[0032] The coiled-coil structure region spans amino acid residues 290-526 of the sequence set forth in SEQ ID NO:13, residues 256-442 of the sequence set forth in SEQ ID NO:14, residues 256-476 of the sequence set forth in SEQ ID NO:15, residues 428-637 of the sequence set forth in SEQ ID NO:22, residues 216-425 or 540-786 of the sequence set forth in SEQ ID NO:23, residues 423-632 of the sequence set forth in SEQ ID NO:24, residues 431-640 or 755-901 of the sequence set forth in SEQ ID NO:31, residues 291-398 or 629-668 of the sequence set forth in SEQ ID NO:105, or residues 473-724 or 725-968 of the sequence set forth in SEQ ID NO:107.

[0033] The term "proline-rich region" as used herein, refers to a region of a protein kinase whose proline content over a given amino acid length is higher than the average content of this amino acid found in proteins (*i.e.*, >10%). Proline-rich regions are easily discernable by visual inspection of amino acid sequences and quantitated by standard computer sequence analysis programs such as the DNASTar program EditSeq. Proline-rich regions have been demonstrated to participate in regulatory protein-protein interactions. Among these interactions, those that are most relevant to this invention involve the "PxxP" (SEQ ID NO: 148) proline rich motif found in certain protein kinases (*i.e.*, human PAK1) and the SH3 domain of the adaptor molecule Nck (Galisteo, M.L. *et al.* (1996) *J. Biol. Chem.* 271:20997-21000). Other regulatory interactions involving "PxxP" (SEQ ID NO: 148) proline-rich motifs include the WW domain (Sudol, M. (1996) *Prog. Biochys. Mol. Bio.* 65:113-132).

[0034] The proline-rich region spans amino acid residues 527-640 of the sequence set forth in SEQ ID NO:13, residues 443-626 of the sequence set forth in SEQ ID NO:14, residues 477-680 of the sequence set forth in SEQ ID NO:15, residues 347-534 of the

sequence set forth in SEQ ID NO:18, residues 398-628 of the sequence set forth in SEQ ID NO:105, or residues 338-472 of the sequence set forth in SEQ ID NO:107.

[0035] The term "spacer region" as used herein, refers to a region of the protein kinase located between predicted functional domains. The spacer region has no detectable homology to any amino acid sequence in the database, and can be identified by using a Smith-Waterman alignment of the protein sequence against the non-redundant protein database to define the C- and N-terminal boundaries of the flanking functional domains. Spacer regions may or may not play a fundamental role in protein kinase function. Precedence for the regulatory role of spacer regions in kinase function is provided by the role of the src kinase spacer in inter-domain interactions (Xu, W. *et al.* (1997) *Nature* 385:595-602).

[0036] The spacer region spans amino acid residues 641-896 of the sequence set forth in SEQ ID NO:13, residues 627-954 of the sequence set forth in SEQ ID NO:14, residues 681-983 of the sequence set forth in SEQ ID NO:15, residues 274-346 of the sequence set forth in SEQ ID NO:18, residues 278-427 or 638-751 of the sequence set forth in SEQ ID NO:22, residues 67-215 or 426-539 of the sequence set forth in SEQ ID NO:23, residues 274-422 or 633-748 of the sequence set forth in SEQ ID NO:24, residues 225-393 of the sequence set forth in SEQ ID NO:29, residues 282-430 or 641-754 of the sequence set forth in SEQ ID NO:31, residues 174-307 of the sequence set forth in SEQ ID NO:103, residues 669-872 of the sequence set forth in SEQ ID NO:105, or residues 295-337 of the sequence set forth in SEQ ID NO:107.

[0037] The term "insert" as used herein refers to a portion of a protein kinase that is absent from a close homolog. Inserts may or may not be the product alternative splicing of exons. Inserts can be identified by using a Smith-Waterman sequence alignment of the protein sequence against the non-redundant protein database, or by means of a multiple sequence alignment of homologous sequences using the DNASTar program Megalign. Inserts may play a functional role by presenting a new interface for protein-protein interactions, or by interfering with such interactions. Inserts span amino acid residues 52-224 of the sequence set forth in SEQ ID NO:29 or residues 53-173 of the sequence set forth in SEQ ID NO:103.

[0038] The term "C-terminal tail" as used herein, refers to a C-terminal domain of

a protein kinase, that by homology extends or protrudes past the C-terminal amino acid of its closest homolog. C-terminal tails can be identified by using a Smith-Waterman sequence alignment of the protein sequence against the non-redundant protein database, or by means of a multiple sequence alignment of homologous sequences using the DNASTar program Megalign. Depending on its length, a C-terminal tail may or may not play a regulatory role in kinase function.

[0039] The C-terminal tail spans amino acid residues 490-516 of the sequence set forth in SEQ ID NO:6, residues 787-887 of the sequence set forth in SEQ ID NO:23, residues 659-681 of the sequence set forth in SEQ ID NO:29, residues 994-1093 of the sequence set forth in SEQ ID NO:31, or residues 573-591 of the sequence set forth in SEQ ID NO:103.

[0040] Various low or high stringency hybridization conditions may be used depending upon the specificity and selectivity desired. These conditions are well-known to those skilled in the art. Under stringent hybridization conditions only highly complementary nucleic acid sequences hybridize. Preferably, such conditions prevent hybridization of nucleic acids having more than 1 or 2 mismatches out of 20 contiguous nucleotides, more preferably, such conditions prevent hybridization of nucleic acids having more than 1 or 2 mismatches out of 50 contiguous nucleotides, most preferably, such conditions prevent hybridization of nucleic acids having more than 1 or 2 mismatches out of 100 contiguous nucleotides. In some instances, the conditions may prevent hybridization of nucleic acids having more than 5 mismatches in the full-length sequence.

[0041] By stringent hybridization assay conditions is meant hybridization assay conditions at least as stringent as the following: hybridization in 50% formamide, 5X SSC, 50 mM NaH_2PO_4 , pH 6.8, 0.5% SDS, 0.1 mg/mL sonicated salmon sperm DNA, and 5X Denhart solution at 42 °C overnight; washing with 2X SSC, 0.1% SDS at 45 °C; and washing with 0.2X SSC, 0.1% SDS at 45 °C. Under some of the most stringent hybridization assay conditions, the second wash can be done with 0.1X SSC at a temperature up to 70 °C (Berger et al. (1987) Guide to Molecular Cloning Techniques pg 421, hereby incorporated by reference herein including any figures, tables, or drawings.). However, other applications may require the use of conditions falling between these sets of conditions. Methods of determining the conditions required to achieve desired

hybridizations are well-known to those with ordinary skill in the art, and are based on several factors, including but not limited to, the sequences to be hybridized and the samples to be tested.

[0042] In other preferred embodiments, the invention features isolated, enriched, or purified nucleic acid molecules encoding kinase polypeptides, further comprising a vector or promoter effective to initiate transcription in a host cell. The invention also features recombinant nucleic acid, preferably in a cell or an organism. The recombinant nucleic acid may contain a sequence set forth in SEQ ID NO:1, SEQ ID NO:2, SEQ ID NO:3, SEQ ID NO:9, SEQ ID NO:10, SEQ ID NO:11, SEQ ID NO:17, SEQ ID NO:19, SEQ ID NO:20, SEQ ID NO:21, SEQ ID NO:27, SEQ ID NO:96, SEQ ID NO:98, SEQ ID NO:100, SEQ ID NO:102, SEQ ID NO:104, or SEQ ID NO:106, or a functional derivative thereof and a vector or a promoter effective to initiate transcription in a host cell. The recombinant nucleic acid can alternatively contain a transcriptional initiation region functional in a cell, a sequence complementary to an RNA sequence encoding a kinase polypeptide and a transcriptional termination region functional in a cell. Specific vectors and host cell combinations are discussed herein.

[0043] The term "vector" relates to a single or double-stranded circular nucleic acid molecule that can be transfected into cells and replicated within or independently of a cell genome. A circular double-stranded nucleic acid molecule can be cut and thereby linearized upon treatment with restriction enzymes. An assortment of nucleic acid vectors, restriction enzymes, and the knowledge of the nucleotide sequences cut by restriction enzymes are readily available to those skilled in the art. A nucleic acid molecule encoding a kinase can be inserted into a vector by cutting the vector with restriction enzymes and ligating the two pieces together.

[0044] The term "transfecting" defines a number of methods to insert a nucleic acid vector or other nucleic acid molecules into a cellular organism. These methods involve a variety of techniques, such as treating the cells with high concentrations of salt, an electric field, detergent, or DMSO to render the outer membrane or wall of the cells permeable to nucleic acid molecules of interest or use of various viral transduction strategies.

[0045] The term "promoter" as used herein, refers to nucleic acid sequence needed

for gene sequence expression. Promoter regions vary from organism to organism, but are well known to persons skilled in the art for different organisms. For example, in prokaryotes, the promoter region contains both the promoter (which directs the initiation of RNA transcription) as well as the DNA sequences which, when transcribed into RNA, will signal synthesis initiation. Such regions will normally include those 5'-non-coding sequences involved with initiation of transcription and translation, such as the TATA box, capping sequence, CAAT sequence, and the like.

[0046] In preferred embodiments, the isolated nucleic acid comprises, consists essentially of, or consists of a nucleic acid sequence set forth in SEQ ID NO:1, SEQ ID NO:2, SEQ ID NO:3, SEQ ID NO:9, SEQ ID NO:10, SEQ ID NO:11, SEQ ID NO:17, SEQ ID NO:19, SEQ ID NO:20, SEQ ID NO:21, SEQ ID NO:27, SEQ ID NO:96, SEQ ID NO:98, SEQ ID NO:100, SEQ ID NO:102, SEQ ID NO:104, or SEQ ID NO:106, or the corresponding full-length sequence, encodes the amino acid sequence of SEQ ID NO:5, SEQ ID NO:6, SEQ ID NO:7, SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, SEQ ID NO:18, SEQ ID NO:22, SEQ ID NO:23, SEQ ID NO:24, SEQ ID NO:29, SEQ ID NO:31, SEQ ID NO:97, SEQ ID NO:99, SEQ ID NO:101, SEQ ID NO:103, SEQ ID NO:105, or SEQ ID NO:107, or the corresponding full-length amino acid sequence, a functional derivative thereof, or at least 40, 45, 50, 60, 100, 200, or 300 contiguous amino acids of SEQ ID NO:5, SEQ ID NO:6, or SEQ ID NO:7, or of the corresponding full-length amino acid sequence; at least 250, 255, 275, 300, or 400 contiguous amino acids of SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, or of the corresponding full-length amino acid sequence; at least 27, 30, 35, 40, 50, 100, 200, or 300 contiguous amino acids of SEQ ID NO:18; at least 16, 25, 35, 50, 100, 200, or 300 contiguous amino acids of SEQ ID NO:22, SEQ ID NO:23, SEQ ID NO:24, SEQ ID NO:29, SEQ ID NO:31, or SEQ ID NO:103, or of the corresponding full-length amino acid sequence; 6 (preferably 10, more preferably 15, most preferably 25) or more contiguous amino acids set forth in the amino acid sequence of SEQ ID NO:97 or SEQ ID NO:99, or the corresponding full-length amino acid sequence; 22 (preferably 30, more preferably 35, most preferably 45) or more contiguous amino acids set forth in the amino acid sequence of SEQ ID NO:101, or the corresponding full-length amino acid sequence; or at least 80, 85, 90, 100, 200, or 300 contiguous amino acids of SEQ ID NO:107, or functional derivatives thereof. The kinase

polypeptides, selected from the group consisting of STLK2, STLK3, STLK4, STLK5, STLK6, STLK7, ZC1, ZC2, ZC3, ZC4, KHS2, SULU1, SULU3, GEK2, PAK4, and PAK5, comprise, consist essentially of, or consist of at least at least 40, 45, 50, 60, 100, 200, or 300 contiguous amino acids of SEQ ID NO:5, SEQ ID NO:6, or SEQ ID NO:7; at least 250, 255, 275, 300, or 400 contiguous amino acids of SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, or SEQ ID NO:105; at least 27, 30, 35, 40, 50, 100, 200, or 300 contiguous amino acids of SEQ ID NO:18; at least 35, 40, 45, 50, 100, 200, or 300 contiguous amino acids of SEQ ID NO:22, SEQ ID NO:23, SEQ ID NO:24, SEQ ID NO:29, SEQ ID NO:31 or SEQ ID NO:103; 6 (preferably 10, more preferably 15, most preferably 25) or more contiguous amino acids set forth in the amino acid sequence of SEQ ID NO:97 or SEQ ID NO:99; 22 (preferably 30, more preferably 35, most preferably 45) or more contiguous amino acids set forth in the amino acid sequence of SEQ ID NO:101; or at least 80, 85, 90, 100, 200, or 300 contiguous amino acids of SEQ ID NO:107, or the corresponding full-length sequences or derivatives thereof. The nucleic acid may be isolated from a natural source by cDNA cloning or by subtractive hybridization. The natural source may be mammalian, preferably human, blood, semen, or tissue, and the nucleic acid may be synthesized by the triester method or by using an automated DNA synthesizer.

[0047] The term "mammal" refers preferably to such organisms as mice, rats, rabbits, guinea pigs, sheep, and goats, more preferably to cats, dogs, monkeys, and apes, and most preferably to humans.

[0048] In yet other preferred embodiments, the nucleic acid is a conserved or unique region, for example those useful for: the design of hybridization probes to facilitate identification and cloning of additional polypeptides, the design of PCR probes to facilitate cloning of additional polypeptides, obtaining antibodies to polypeptide regions, and designing antisense oligonucleotides.

[0049] By "conserved nucleic acid regions", are meant regions present on two or more nucleic acids encoding a kinase polypeptide, to which a particular nucleic acid sequence can hybridize under lower stringency conditions. Examples of lower stringency conditions suitable for screening for nucleic acid encoding kinase polypeptides are provided in Abe, *et al.* (J. Biol. Chem. 19:13361-13368, 1992), hereby incorporated by

reference herein in its entirety, including any drawings, figures, or tables. Preferably, conserved regions differ by no more than 5 out of 20 nucleotides, even more preferably 2 out of 20 nucleotides or most preferably 1 out of 20 nucleotides.

[0050] By "unique nucleic acid region" is meant a sequence present in a nucleic acid coding for a kinase polypeptide that is not present in a sequence coding for any other naturally occurring polypeptide. Such regions preferably encode 32 (preferably 40, more preferably 45, most preferably 55) or more contiguous amino acids set forth in the amino acid sequence of SEQ ID NO:5, SEQ ID NO:6, or SEQ ID NO:7, or the corresponding full-length amino acid sequence; 250 (preferably 255, more preferably 260, most preferably 270) or more contiguous amino acids set forth in the amino acid sequence SEQ ID NO:13, SEQ ID NO:14, or SEQ ID NO:15, or SEQ ID NO:105, or the corresponding full-length amino acid sequence; 27 (preferably 30, more preferably 40, most preferably 45) or more contiguous amino acids set forth in the amino acid sequence SEQ ID NO:18; 16 (preferably 20, more preferably 25, most preferably 35) or more contiguous amino acids set forth in the amino acid sequence SEQ ID NO:22, SEQ ID NO:23, SEQ ID NO:24, SEQ ID NO:29, SEQ ID NO:31, or SEQ ID NO:103, or the corresponding full-length amino acid sequence; 6 (preferably 10, more preferably 15, most preferably 25) or more contiguous amino acids set forth in the amino acid sequence of SEQ ID NO:97 or SEQ ID NO:99, 22 (preferably 30, more preferably 35, most preferably 45) or more contiguous amino acids set forth in the amino acid sequence of SEQ ID NO:101, or the corresponding full-length amino acid sequence; or 78 (preferably 80, more preferably 85, most preferably 90) or more contiguous amino acids set forth in the amino acid sequence SEQ ID NO:107, or functional derivatives thereof. In particular, a unique nucleic acid region is preferably of mammalian origin.

[0051] A second aspect of the invention features a nucleic acid probe for the detection of nucleic acid encoding a kinase polypeptide in a sample, wherein said polypeptide is selected from the group consisting of STLK2, STLK3, STLK4, STLK5, STLK6, STLK7, ZC1, ZC2, ZC3, ZC4, KHS2, SULU1, SULU3, GEK2, PAK4, and PAK5. Preferably, the nucleic acid probe encodes a kinase polypeptide that is a fragment of the protein encoded by the amino acid sequence set forth in SEQ ID NO:5, SEQ ID NO:6, SEQ ID NO:7, SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, SEQ ID NO:18,

SEQ ID NO:22, SEQ ID NO:23, SEQ ID NO:24, SEQ ID NO:29, SEQ ID NO:31, SEQ ID NO:97, SEQ ID NO:99, SEQ ID NO:101, SEQ ID NO:103, SEQ ID NO:105, or SEQ ID NO:107, or the corresponding full-length amino acid sequences, not to include fragments consisting only of amino acids 1-22 of SEQ ID NO:13 or amino acids 1-33 of SEQ ID NO:107. The nucleic acid probe contains a nucleotide base sequence that will hybridize to a sequence set forth in SEQ ID NO:1, SEQ ID NO:2, SEQ ID NO:3, SEQ ID NO:9, SEQ ID NO:10, SEQ ID NO:11, SEQ ID NO:17, SEQ ID NO:19, SEQ ID NO:20, SEQ ID NO:21, SEQ ID NO:27, SEQ ID NO:96, SEQ ID NO:98, SEQ ID NO:100, SEQ ID NO:102, SEQ ID NO:104, or SEQ ID NO:106, or the corresponding full-length sequence, or a functional derivative thereof.

[0052] In preferred embodiments, the nucleic acid probe hybridizes to nucleic acid encoding at least 6, 12, 75, 90, 105, 120, 150, 200, 250, 300 or 350 contiguous amino acids of the sequence set forth in SEQ ID NO:5, SEQ ID NO:6, SEQ ID NO:7, SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, SEQ ID NO:18, SEQ ID NO:22, SEQ ID NO:23, SEQ ID NO:24, SEQ ID NO:29, SEQ ID NO:31, SEQ ID NO:97, SEQ ID NO:99, SEQ ID NO:101, SEQ ID NO:103, SEQ ID NO:105, or SEQ ID NO:107, or the corresponding full-length amino acid sequence, or functional derivatives thereof.

[0053] Methods for using the probes include detecting the presence or amount of kinase RNA in a sample by contacting the sample with a nucleic acid probe under conditions such that hybridization occurs and detecting the presence or amount of the probe bound to kinase RNA. The nucleic acid duplex formed between the probe and a nucleic acid sequence coding for a kinase polypeptide may be used in the identification of the sequence of the nucleic acid detected (Nelson *et al.*, in *Nonisotopic DNA Probe Techniques*, Academic Press, San Diego, Kricka, ed., p. 275, 1992, hereby incorporated by reference herein in its entirety, including any drawings, figures, or tables). Kits for performing such methods may be constructed to include a container means having disposed therein a nucleic acid probe.

[0054] In a third aspect, the invention describes a recombinant cell or tissue comprising a nucleic acid molecule encoding a kinase polypeptide selected from the group consisting of STLK2, STLK3, STLK4, STLK5, STLK6, STLK7, ZC1, ZC2, ZC3, ZC4, KHS2, SULU1, SULU3, GEK2, PAK4, and PAK5. In such cells, the nucleic acid may be

under the control of the genomic regulatory elements, or may be under the control of exogenous regulatory elements including an exogenous promoter. By "exogenous" it is meant a promoter that is not normally coupled *in vivo* transcriptionally to the coding sequence for the kinase polypeptides.

[0055] The polypeptide is preferably a fragment of the protein encoded by the amino acid sequence set forth in SEQ ID NO:5, SEQ ID NO:6, SEQ ID NO:7, SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, SEQ ID NO:18, SEQ ID NO:22, SEQ ID NO:23, SEQ ID NO:24, SEQ ID NO:29, SEQ ID NO:31, SEQ ID NO:97, SEQ ID NO:99, SEQ ID NO:101, SEQ ID NO:103, SEQ ID NO:105, or SEQ ID NO:107, or the corresponding full-length amino acid sequence, not to include fragments consisting only of amino acids 1-22 of SEQ ID NO:13 or amino acids 1-33 of SEQ ID NO:107. By "fragment," is meant an amino acid sequence present in a kinase polypeptide. Preferably, such a sequence comprises at least 32, 45, 50, 60, 100, 200, or 300 contiguous amino acids of SEQ ID NO:5, SEQ ID NO:6, or SEQ ID NO:7, or of the corresponding full-length amino acid sequence; at least 250, 255, 275, 300, or 400 contiguous amino acids of SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, OR SEQ ID NO:105, or of the corresponding full-length amino acid sequence; at least 27, 30, 35, 40, 50, 100, 200, or 300 contiguous amino acids of SEQ ID NO:18; at least 16, 25, 35, 50, 100, 200, or 300 contiguous amino acids of SEQ ID NO:22, SEQ ID NO:23, SEQ ID NO:24, SEQ ID NO:29, SEQ ID NO:31 or SEQ ID NO:103, or of the corresponding full-length amino acid sequence; 6 (preferably 10, more preferably 15, most preferably 25) or more contiguous amino acids set forth in the amino acid sequence of SEQ ID NO:97 or SEQ ID NO:99, 22 (preferably 30, more preferably 35, most preferably 45) or more contiguous amino acids set forth in the amino acid sequence of SEQ ID NO:101; at least 78, 85, 90, 100, 200, or 300 contiguous amino acids of SEQ ID NO:107, or the corresponding full-length amino acid sequence; or a functional derivative thereof.

[0056] In a fourth aspect, the invention features an isolated, enriched, or purified kinase polypeptide selected from the group consisting of STLK2, STLK3, STLK4, STLK5, STLK6, STLK7, ZC1, ZC2, ZC3, ZC4, KHS2, SULU1, SULU3, GEK2, PAK4, and PAK5.

[0057] By "isolated" in reference to a polypeptide is meant a polymer of amino

acids (2 or more amino acids) conjugated to each other, including polypeptides that are isolated from a natural source or that are synthesized. The isolated polypeptides of the present invention are unique in the sense that they are not found in a pure or separated state in nature. Use of the term "isolated" indicates that a naturally occurring sequence has been removed from its normal cellular environment. Thus, the sequence may be in a cell-free solution or placed in a different cellular environment. The term does not imply that the sequence is the only amino acid chain present, but that it is essentially free (about 90 - 95% pure at least) of non-amino acid material naturally associated with it.

[0058] By the use of the term "enriched" in reference to a polypeptide is meant that the specific amino acid sequence constitutes a significantly higher fraction (2 - 5 fold) of the total amino acid sequences present in the cells or solution of interest than in normal or diseased cells or in the cells from which the sequence was taken. This could be caused by a person by preferential reduction in the amount of other amino acid sequences present, or by a preferential increase in the amount of the specific amino acid sequence of interest, or by a combination of the two. However, it should be noted that enriched does not imply that there are no other amino acid sequences present, just that the relative amount of the sequence of interest has been significantly increased. The term significant here is used to indicate that the level of increase is useful to the person making such an increase, and generally means an increase relative to other amino acid sequences of about at least 2-fold, more preferably at least 5- to 10-fold or even more. The term also does not imply that there is no amino acid sequence from other sources. The other source of amino acid sequences may, for example, comprise amino acid sequence encoded by a yeast or bacterial genome, or a cloning vector such as pUC19. The term is meant to cover only those situations in which man has intervened to increase the proportion of the desired amino acid sequence.

[0059] It is also advantageous for some purposes that an amino acid sequence be in purified form. The term "purified" in reference to a polypeptide does not require absolute purity (such as a homogeneous preparation); instead, it represents an indication that the sequence is relatively purer than in the natural environment. Compared to the natural level this level should be at least 2-5 fold greater (*e.g.*, in terms of mg/mL). Purification of at least one order of magnitude, preferably two or three orders, and more preferably four or

five orders of magnitude is expressly contemplated. The substance is preferably free of contamination at a functionally significant level, for example 90%, 95%, or 99% pure.

[0060] In preferred embodiments, the kinase polypeptide is a fragment of the protein encoded by the amino acid sequence set forth in SEQ ID NO:5, SEQ ID NO:6, SEQ ID NO:7, SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, SEQ ID NO:18, SEQ ID NO:22, SEQ ID NO:23, SEQ ID NO:24, SEQ ID NO:29, SEQ ID NO:31, SEQ ID NO:97, SEQ ID NO:99, SEQ ID NO:101, SEQ ID NO:103, SEQ ID NO:105, or SEQ ID NO:107, or the corresponding full-length amino acid sequences, not to include fragments consisting only of amino acids 1-22 of SEQ ID NO:13 or amino acids 1-33 of SEQ ID NO:107. Preferably, the kinase polypeptide contains at least 32, 45, 50, 60, 100, 200, or 300 contiguous amino acids of SEQ ID NO:5, SEQ ID NO:6, or SEQ ID NO:7, or the corresponding full-length amino acid sequence; at least 250, 255, 275, 300, or 400 contiguous amino acids of SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, or SEQ ID NO:105, or the corresponding full-length amino acid sequence; at least 27, 30, 35, 40, 50, 100, 200, or 300 contiguous amino acids of SEQ ID NO:18; at least 16, 25, 35, 50, 100, 200, or 300 contiguous amino acids of SEQ ID NO:22, SEQ ID NO:23, SEQ ID NO:24, SEQ ID NO:29, SEQ ID NO:31, or SEQ ID NO:103, or the corresponding full-length amino acid sequence; 6 (preferably 10, more preferably 15, most preferably 25) or more contiguous amino acids set forth in the amino acid sequence of SEQ ID NO:97 or SEQ ID NO:99, 22 (preferably 30, more preferably 35, most preferably 45) or more contiguous amino acids set forth in the amino acid sequence of SEQ ID NO:101, or the corresponding full-length amino acid sequence; or at least 78, 85, 90, 100, 200, or 300 contiguous amino acids of SEQ ID NO:107, or a functional derivative thereof.

[0061] In preferred embodiments, the kinase polypeptide comprises an amino acid sequence having (a) the amino acid sequence set forth in SEQ ID NO:5, SEQ ID NO:6, SEQ ID NO:7, SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, SEQ ID NO:18, SEQ ID NO:22, SEQ ID NO:23, SEQ ID NO:24, SEQ ID NO:29, SEQ ID NO:31, SEQ ID NO:97, SEQ ID NO:99, SEQ ID NO:101, SEQ ID NO:103, SEQ ID NO:105, or SEQ ID NO:107; (b) the amino acid sequence set forth in SEQ ID NO:5, SEQ ID NO:6, SEQ ID NO:7, SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, SEQ ID NO:18, SEQ ID NO:22, SEQ ID NO:23, SEQ ID NO:24, SEQ ID NO:29, SEQ ID NO:31, SEQ ID NO:97, SEQ ID NO:99,

SEQ ID NO:103, SEQ ID NO:105, or SEQ ID NO:107, except that it lacks one or more, but not all, of the following segments of amino acid residues: 1-21, 22-274, or 275-416 of SEQ ID NO:5, 1-31, 32-308, 309-489 or 490-516 of SEQ ID NO:6, 1-178 or 179-414 of SEQ ID NO:7, 1-22, 23-289, 290-526, 527-640, 641-896, or 897-1239 of SEQ ID NO:13, 1-255, 256-442, 443-626, 627-954, or 955-1297 of SEQ ID NO:14, 1-255, 256-476, 477-680, 681-983, or 984-1326 of SEQ ID NO:15, 1-13, 14-273, 274-346, 347-534, or 535-894 of SEQ ID NO:18, 1-21, 22-277, 278-427, 428-637, 638-751, or 752-898 of SEQ ID NO:22, 1-66, 67-215, 216-425, 426-539, 540-786, or 787-887 of SEQ ID NO:23, 1-25, 26-273, 274-422, 423-632, or 633-748 of SEQ ID NO:24, 1-51, 52-224, 225-393, 394-658, or 659-681 of SEQ ID NO:29, 1-25, 26-281, 282-430, 431-640, 641-754, 755-901, or 902-1001 of SEQ ID NO:31, 1-10, 11-321, or 322-373 of SEQ ID NO:97, 1-57, 58-369, or 370-418 of SEQ ID NO:99, 1-52, 53-173, 174-307, 308-572, or 573-591 of SEQ ID NO:103, 1-24, 25-289, 290-397, 398-628, 629-668, 669-872, or 873-1227 of SEQ ID NO:105, or 1-33, 34-294, 295-337, 338-472, 473-724, or 725-968 of SEQ ID NO:107; (c) the amino acid sequence set forth in SEQ ID NO:5, SEQ ID NO:6, SEQ ID NO:7, SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, SEQ ID NO:18, SEQ ID NO:22, SEQ ID NO:23, SEQ ID NO:24, SEQ ID NO:29, SEQ ID NO:97, SEQ ID NO:99, SEQ ID NO:103, SEQ ID NO:105, or SEQ ID NO:107 from amino acid residues 1-21, 22-274, or 275-416 of SEQ ID NO:5, 1-31, 32-308, 309-489, or 490-516 of SEQ ID NO:6, 1-178 or 179-414 of SEQ ID NO:7, 23-289, 290-526, 527-640, 641-896, or 897-1239 of SEQ ID NO:13, 1-255, 256-442, 443-626, 627-954, or 955-1297 of SEQ ID NO:14, 1-255, 256-476, 477-680, 681-983, or 984-1326 of SEQ ID NO:15, 1-13, 14-273, 274-346, 347-534, or 535-894 of SEQ ID NO:18, 1-21, 22-277, 278-427, 428-637, 638-751, or 752-898 of SEQ ID NO:22, 1-66, 67-215, 216-425, 426-539, 540-786, or 787-887 of SEQ ID NO:23, 1-25, 26-273, 274-422, 423-632, or 633-748 of SEQ ID NO:24, 1-51, 52-224, 225-393, 394-658, or 659-681 of SEQ ID NO:29, 1-25, 26-273, 274-422, 423-632, 633-746, 747-993, or 994-1093 of SEQ ID NO:31, 1-10, 11-321, or 322-373 of SEQ ID NO:97, 1-57, 58-369, or 370-418 of SEQ ID NO:99, 1-52, 53-173, 174-307, 308-572, or 573-591 of SEQ ID NO:103, 1-24, 25-289, 290-397, 398-628, 629-668, 669-872, or 873-1227 of SEQ ID NO:105, or 1-33, 34-294, 295-337, 338-472, 473-724, or 725-968 of SEQ ID NO:107; or (d) the amino acid sequence set forth in SEQ ID NO:5, SEQ ID NO:6, SEQ ID NO:7, SEQ ID NO:13, SEQ

ID NO:14, SEQ ID NO:15, SEQ ID NO:18, SEQ ID NO:22, SEQ ID NO:23, SEQ ID NO:24, SEQ ID NO:29, SEQ ID NO:31, SEQ ID NO:97, SEQ ID NO:99, SEQ ID NO:101, SEQ ID NO:103, SEQ ID NO:105, or SEQ ID NO:107, except that it lacks one or more, but not all, of the domains selected from the group consisting of a C-terminal domain, a catalytic domain, an N-terminal domain, a spacer region, a proline-rich region, a coiled-coil structure region, an insert, and a C-terminal tail.

[0062] The polypeptide can be isolated from a natural source by methods well-known in the art. The natural source may be mammalian, preferably human, blood, semen, or tissue, and the polypeptide may be synthesized using an automated polypeptide synthesizer. The isolated, enriched, or purified kinase polypeptide is preferably: a STLK2, STLK3, STLK4, STLK5, STLK6, or STLK7 polypeptide; a ZC1, ZC2, ZC3, or ZC4 polypeptide; a KHS2 polypeptide; a SULU1 or SULU3 polypeptide; a GEK2 polypeptide; or a PAK4 or PAK5 polypeptide.

[0063] In some embodiments the invention includes a recombinant kinase polypeptide selected from the group consisting of STLK2, STLK3, STLK4, STLK5, STLK6, STLK7, ZC1, ZC2, ZC3, ZC4, KHS2, SULU1, SULU3, GEK2, PAK4, and PAK5. By "recombinant kinase polypeptide" is meant a polypeptide produced by recombinant DNA techniques such that it is distinct from a naturally occurring polypeptide either in its location (*e.g.*, present in a different cell or tissue than found in nature), purity or structure. Generally, such a recombinant polypeptide will be present in a cell in an amount different from that normally observed in nature.

[0064] In a fifth aspect, the invention features an antibody (*e.g.*, a monoclonal or polyclonal antibody) having specific binding affinity to a kinase polypeptide or a kinase polypeptide domain or fragment where the polypeptide is selected from the group consisting of STLK2, STLK3, STLK4, STLK5, STLK6, STLK7, ZC1, ZC2, ZC3, ZC4, KHS2, SULU1, SULU3, GEK2, PAK4, and PAK5. By "specific binding affinity" is meant that the antibody binds to the target kinase polypeptide with greater affinity than it binds to other polypeptides under specified conditions. Antibodies or antibody fragments are polypeptides that contain regions that can bind other polypeptides. The term "specific binding affinity" describes an antibody that binds to a kinase polypeptide with greater affinity than it binds to other polypeptides under specified conditions.

[0065] The term “polyclonal” refers to antibodies that are heterogenous populations of antibody molecules derived from the sera of animals immunized with an antigen or an antigenic functional derivative thereof. For the production of polyclonal antibodies, various host animals may be immunized by injection with the antigen. Various adjuvants may be used to increase the immunological response, depending on the host species.

[0066] “Monoclonal antibodies” are substantially homogenous populations of antibodies to a particular antigen. They may be obtained by any technique which provides for the production of antibody molecules by continuous cell lines in culture. Monoclonal antibodies may be obtained by methods known to those skilled in the art (Kohler et al., Nature 256:495-497, 1975, and U.S. Patent No. 4,376,110, both of which are hereby incorporated by reference herein in their entirety including any figures, tables, or drawings).

[0067] The term “antibody fragment” refers to a portion of an antibody, often the hyper variable region and portions of the surrounding heavy and light chains, that displays specific binding affinity for a particular molecule. A hyper variable region is a portion of an antibody that physically binds to the polypeptide target.

[0068] Antibodies or antibody fragments having specific binding affinity to a kinase polypeptide of the invention may be used in methods for detecting the presence and/or amount of kinase polypeptide in a sample by probing the sample with the antibody under conditions suitable for kinase-antibody immunocomplex formation and detecting the presence and/or amount of the antibody conjugated to the kinase polypeptide. Diagnostic kits for performing such methods may be constructed to include antibodies or antibody fragments specific for the kinase as well as a conjugate of a binding partner of the antibodies or the antibodies themselves.

[0069] An antibody or antibody fragment with specific binding affinity to a kinase polypeptide of the invention can be isolated, enriched, or purified from a prokaryotic or eukaryotic organism. Routine methods known to those skilled in the art enable production of antibodies or antibody fragments, in both prokaryotic and eukaryotic organisms. Purification, enrichment, and isolation of antibodies, which are polypeptide molecules, are described above.

[0070] Antibodies having specific binding affinity to a kinase polypeptide of the invention may be used in methods for detecting the presence and/or amount of kinase polypeptide in a sample by contacting the sample with the antibody under conditions such that an immunocomplex forms and detecting the presence and/or amount of the antibody conjugated to the kinase polypeptide. Diagnostic kits for performing such methods may be constructed to include a first container containing the antibody and a second container having a conjugate of a binding partner of the antibody and a label, such as, for example, a radioisotope. The diagnostic kit may also include notification of an FDA approved use and instructions therefor.

[0071] In a sixth aspect, the invention features a hybridoma which produces an antibody having specific binding affinity to a kinase polypeptide or a kinase polypeptide domain, where the polypeptide is selected from the group consisting of STLK2, STLK3, STLK4, STLK5, STLK6, STLK7, ZC1, ZC2, ZC3, ZC4, KHS2, SULU1, SULU3, GEK2, PAK4, and PAK5. By "hybridoma" is meant an immortalized cell line that is capable of secreting an antibody, for example an antibody to a kinase of the invention. In preferred embodiments, the antibody to the kinase comprises a sequence of amino acids that is able to specifically bind a kinase polypeptide of the invention.

[0072] In a seventh aspect, the invention features a kinase polypeptide binding agent able to bind to a kinase polypeptide selected from the group consisting of STLK2, STLK3, STLK4, STLK6, STLK7, STLK5, ZC1, ZC2, ZC3, ZC4, KHS2, SULU1, SULU3, GEK2, PAK4, and PAK5. The binding agent is preferably a purified antibody that recognizes an epitope present on a kinase polypeptide of the invention. Other binding agents include molecules that bind to kinase polypeptides and analogous molecules that bind to a kinase polypeptide. Such binding agents may be identified by using assays that measure kinase binding partner activity, such as those that measure PDGFR activity.

[0073] The invention also features a method for screening for human cells containing a kinase polypeptide of the invention or an equivalent sequence. The method involves identifying the novel polypeptide in human cells using techniques that are routine and standard in the art, such as those described herein for identifying the kinases of the invention (*e.g.*, cloning, Southern or Northern blot analysis, in situ hybridization, PCR amplification, etc.).

[0074] In an eighth aspect, the invention features methods for identifying a substance that modulates kinase activity comprising the steps of: (a) contacting a kinase polypeptide selected from the group consisting of STLK2, STLK3, STLK4, STLK5, STLK6, STLK7, ZC1, ZC2, ZC3, ZC4, KHS2, SULU1, SULU3, GEK2, PAK4, and PAK5 with a test substance; (b) measuring the activity of said polypeptide; and (c) determining whether said substance modulates the activity of said polypeptide.

[0075] The term “modulates” refers to the ability of a compound to alter the function of a kinase of the invention. A modulator preferably activates or inhibits the activity of a kinase of the invention depending on the concentration of the compound exposed to the kinase.

[0076] The term “activates” refers to increasing the cellular activity of the kinase. The term inhibit refers to decreasing the cellular activity of the kinase. Kinase activity is preferably the interaction with a natural binding partner.

[0077] The term “modulates” also refers to altering the function of kinases of the invention by increasing or decreasing the probability that a complex forms between the kinase and a natural binding partner. A modulator preferably increases the probability that such a complex forms between the kinase and the natural binding partner, more preferably increases or decreases the probability that a complex forms between the kinase and the natural binding partner depending on the concentration of the compound exposed to the kinase, and most preferably decreases the probability that a complex forms between the kinase and the natural binding partner.

[0078] The term “complex” refers to an assembly of at least two molecules bound to one another. Signal transduction complexes often contain at least two protein molecules bound to one another. For instance, a protein tyrosine receptor protein kinase, GRB2, SOS, RAF, and RAS assemble to form a signal transduction complex in response to a mitogenic ligand.

[0079] The term “natural binding partner” refers to polypeptides, lipids, small molecules, or nucleic acids that bind to kinases in cells. A change in the interaction between a kinase and a natural binding partner can manifest itself as an increased or decreased probability that the interaction forms, or an increased or decreased concentration of kinase/natural binding partner complex.

[0080] The term “contacting” as used herein refers to mixing a solution comprising the test compound with a liquid medium bathing the cells of the methods. The solution comprising the compound may also comprise another component, such as dimethyl sulfoxide (DMSO), which facilitates the uptake of the test compound or compounds into the cells of the methods. The solution comprising the test compound may be added to the medium bathing the cells by utilizing a delivery apparatus, such as a pipet-based device or syringe-based device.

[0081] In a ninth aspect, the invention features methods for identifying a substance that modulates kinase activity in a cell comprising the steps of: (a) expressing a kinase polypeptide in a cell, wherein said polypeptide is selected from the group consisting of STLK2, STLK3, STLK4, STLK5, STLK6, STLK7, ZC1, ZC2, ZC3, ZC4, KHS2, SULU1, SULU3, GEK2, PAK4, and PAK5; (b) adding a test substance to said cell; and (c) monitoring a change in cell phenotype or the interaction between said polypeptide and a natural binding partner.

[0082] The term “expressing” as used herein refers to the production of kinases of the invention from a nucleic acid vector containing kinase genes within a cell. The nucleic acid vector is transfected into cells using well known techniques in the art as described herein.

[0083] In a tenth aspect, the invention provides methods for treating a disease by administering to a patient in need of such treatment a substance that modulates the activity of a kinase selected from the group consisting of STLK2, STLK3, STLK4, STLK5, STLK6, STLK7, ZC1, ZC2, ZC3, ZC4, KHS2, SULU1, SULU3, GEK2, PAK4, and PAK5. Preferably, the disease is selected from the group consisting of immune-related diseases and disorders, organ transplantation, myocardial infarction, cardiovascular disease, stroke, renal failure, oxidative stress-related neurodegenerative disorders, and cancer. Most preferably, the immune-related diseases and disorders include, but are not limited to, rheumatoid arthritis, arteriosclerosis, and autoimmune disorders.

[0084] In preferred embodiments, the invention provides methods for treating or preventing a disease or disorder by administering to a patient in need of such treatment a substance that modulates the activity of a kinase polypeptide selected from the group consisting of ZC1, ZC2, ZC3, ZC4, KHS2, PAK4, and PAK5. Preferably, the disease or

disorder is selected from the group consisting of rheumatoid arthritis, arteriosclerosis, autoimmune disorders, and organ transplantation. The invention also features methods of treating or preventing a disease or disorder by administering to a patient in need of such treatment a substance that modulates the activity of a kinase polypeptide selected from the group consisting of STK1, STK2, STK3, STK4, STK5, STK6, and STK7. Preferably the disease or disorder is selected from the group consisting of immune-related diseases and disorders, myocardial infarction, cardiomyopathies, stroke, renal failure, and oxidative stress-related neurodegenerative disorders. Most preferably, the immune-related diseases and disorders are selected from the group consisting of rheumatoid arthritis, chronic inflammatory bowel disease, chronic inflammatory pelvic disease, multiple sclerosis, asthma, osteoarthritis, psoriasis, arteriosclerosis, rhinitis, autoimmunity, and organ transplantation.

[0085] The invention also features methods of treating or preventing a disease or disorder by administering to a patient in need of such treatment a substance that modulates the activity of a kinase polypeptide selected from the group consisting of ZC1, ZC2, ZC3, and ZC4. Preferably the disease is selected from the group consisting of immune-related diseases and disorders, cardiovascular disease, and cancer. Most preferably, the immune-related diseases and disorders are selected from the group consisting of rheumatoid arthritis, chronic inflammatory bowel disease, chronic inflammatory pelvic disease, multiple sclerosis, asthma, osteoarthritis, psoriasis, arteriosclerosis, rhinitis, autoimmunity, and organ transplantation.

[0086] Substances useful for treatment of kinase-related disorders or diseases preferably show positive results in one or more *in vitro* assays for an activity corresponding to treatment of the disease or disorder in question (Examples of such assays are provided in the references in section VI, below; and in Example 7, herein). Examples of substances that can be screened for favorable activity are provided and referenced in section VI, below. The substances that modulate the activity of the kinases preferably include, but are not limited to, antisense oligonucleotides and inhibitors of protein kinases, as determined by methods and screens referenced in section VI and Example 7, below.

[0087] The term “preventing” refers to decreasing the probability that an organism contracts or develops an abnormal condition.

[0088] The term “treating” refers to having a therapeutic effect and at least partially alleviating or abrogating an abnormal condition in the organism.

[0089] The term “therapeutic effect” refers to the inhibition or activation factors causing or contributing to the abnormal condition. A therapeutic effect relieves to some extent one or more of the symptoms of the abnormal condition. In reference to the treatment of abnormal conditions, a therapeutic effect can refer to one or more of the following: (a) an increase in the proliferation, growth, and/or differentiation of cells; (b) inhibition (*i.e.*, slowing or stopping) of cell death; (c) inhibition of degeneration; (d) relieving to some extent one or more of the symptoms associated with the abnormal condition; and (e) enhancing the function of the affected population of cells. Compounds demonstrating efficacy against abnormal conditions can be identified as described herein.

[0090] The term “abnormal condition” refers to a function in the cells or tissues of an organism that deviates from their normal functions in that organism. An abnormal condition can relate to cell proliferation, cell differentiation, or cell survival.

[0091] Abnormal cell proliferative conditions include cancers such as fibrotic and mesangial disorders, abnormal angiogenesis and vasculogenesis, wound healing, psoriasis, diabetes mellitus, and inflammation.

[0092] Abnormal differentiation conditions include, but are not limited to neurodegenerative disorders, slow wound healing rates, and slow tissue grafting healing rates.

[0093] Abnormal cell survival conditions relate to conditions in which programmed cell death (apoptosis) pathways are activated or abrogated. A number of protein kinases are associated with the apoptosis pathways. Aberrations in the function of any one of the protein kinases could lead to cell immortality or premature cell death.

[0094] The term “aberration”, in conjunction with the function of a kinase in a signal transduction process, refers to a kinase that is over- or under-expressed in an organism, mutated such that its catalytic activity is lower or higher than wild-type protein kinase activity, mutated such that it can no longer interact with a natural binding partner, is no longer modified by another protein kinase or protein phosphatase, or no longer interacts with a natural binding partner.

[0095] The term “administering” relates to a method of incorporating a compound

into cells or tissues of an organism. The abnormal condition can be prevented or treated when the cells or tissues of the organism exist within the organism or outside of the organism. Cells existing outside the organism can be maintained or grown in cell culture dishes. For cells harbored within the organism, many techniques exist in the art to administer compounds, including (but not limited to) oral, parenteral, dermal, injection, and aerosol applications. For cells outside of the organism, multiple techniques exist in the art to administer the compounds, including (but not limited to) cell microinjection techniques, transformation techniques, and carrier techniques.

[0096] The abnormal condition can also be prevented or treated by administering a compound to a group of cells having an aberration in a signal transduction pathway to an organism. The effect of administering a compound on organism function can then be monitored. The organism is preferably a mouse, rat, rabbit, guinea pig, or goat, more preferably a monkey or ape, and most preferably a human.

[0097] In an eleventh aspect, the invention features methods for detection of a kinase polypeptide in a sample as a diagnostic tool for diseases or disorders, wherein the method comprises the steps of: (a) contacting the sample with a nucleic acid probe which hybridizes under hybridization assay conditions to a nucleic acid target region of a kinase polypeptide selected from the group consisting of STLK2, STLK3, STLK4, STLK5, STLK6, STLK7, ZC1, ZC2, ZC3, ZC4, KHS2, SULU1, SULU3, GEK2, PAK4, and PAK5, said probe comprising the nucleic acid sequence encoding the polypeptide, fragments thereof, and the complements of the sequences and fragments; and (b) detecting the presence or amount of the probe:target region hybrid as an indication of the disease.

[0098] In preferred embodiments of the invention, the disease or disorder is selected from the group consisting of rheumatoid arthritis, arteriosclerosis, autoimmune disorders, organ transplantation, myocardial infarction, cardiomyopathies, stroke, renal failure, oxidative stress-related neurodegenerative disorders, and cancer. In other preferred embodiments, the kinase polypeptide is selected from the group consisting of PAK4 and PAK5, or the polypeptide is selected from the group consisting of ZC1, ZC2, ZC3, and ZC4, and the disease is cancer.

[0099] The kinase "target region" is the nucleotide base sequence set forth in SEQ ID NO:1, SEQ ID NO:2, SEQ ID NO:3, SEQ ID NO:9, SEQ ID NO:10, SEQ ID NO:11,

SEQ ID NO:17, SEQ ID NO:19, SEQ ID NO:20, SEQ ID NO:21, SEQ ID NO:27, SEQ ID NO:96, SEQ ID NO:98, SEQ ID NO:100, SEQ ID NO:102, SEQ ID NO:104, or SEQ ID NO:106, or the corresponding full-length sequences, a functional derivative thereof, or a fragment thereof to which the nucleic acid probe will specifically hybridize. Specific hybridization indicates that in the presence of other nucleic acids the probe only hybridizes detectably with the kinase of the invention's target region. Putative target regions can be identified by methods well known in the art consisting of alignment and comparison of the most closely related sequences in the database.

[0100] In preferred embodiments the nucleic acid probe hybridizes to a kinase target region encoding at least 6, 12, 75, 90, 105, 120, 150, 200, 250, 300 or 350 contiguous amino acids of the sequence set forth in SEQ ID NO:5, SEQ ID NO:6, SEQ ID NO:7, SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, SEQ ID NO:18, SEQ ID NO:22, SEQ ID NO:23, SEQ ID NO:24, SEQ ID NO:29, SEQ ID NO:31, SEQ ID NO:97, SEQ ID NO:99, SEQ ID NO:101, SEQ ID NO:103, SEQ ID NO:105, or SEQ ID NO:107, or the corresponding full-length amino acid sequence, or a functional derivative thereof. Hybridization conditions should be such that hybridization occurs only with the kinase genes in the presence of other nucleic acid molecules. Under stringent hybridization conditions only highly complementary nucleic acid sequences hybridize. Preferably, such conditions prevent hybridization of nucleic acids having more than 1 or 2 mismatches out of 20 contiguous nucleotides. Such conditions are defined supra.

[0101] The diseases for which detection of kinase genes in a sample could be diagnostic include diseases in which kinase nucleic acid (DNA and/or RNA) is amplified in comparison to normal cells. By "amplification" is meant increased numbers of kinase DNA or RNA in a cell compared with normal cells. In normal cells, kinases are typically found as single copy genes. In selected diseases, the chromosomal location of the kinase genes may be amplified, resulting in multiple copies of the gene, or amplification. Gene amplification can lead to amplification of kinase RNA, or kinase RNA can be amplified in the absence of kinase DNA amplification.

[0102] "Amplification" as it refers to RNA can be the detectable presence of kinase RNA in cells, since in some normal cells there is no basal expression of kinase RNA. In other normal cells, a basal level of expression of kinase exists, therefore in these cases

amplification is the detection of at least 1-2-fold, and preferably more, kinase RNA, compared to the basal level.

[0103] The diseases that could be diagnosed by detection of kinase nucleic acid in a sample preferably include cancers. The test samples suitable for nucleic acid probing methods of the present invention include, for example, cells or nucleic acid extracts of cells, or biological fluids. The samples used in the above-described methods will vary based on the assay format, the detection method and the nature of the tissues, cells or extracts to be assayed. Methods for preparing nucleic acid extracts of cells are well known in the art and can be readily adapted in order to obtain a sample that is compatible with the method utilized.

[0104] In a final aspect, the invention features a method for detection of a kinase polypeptide in a sample as a diagnostic tool for a disease or disorder, wherein the method comprises: (a) comparing a nucleic acid target region encoding the kinase polypeptide in a sample, where the kinase polypeptide is selected from the group consisting of STLK2, STLK3, STLK4, STLK5, STLK6, STLK7, ZC1, ZC2, ZC3, ZC4, KHS2, SULU1, SULU3, GEK2, PAK4, and PAK5, or one or more fragments thereof, with a control nucleic acid target region encoding the kinase polypeptide, or one or more fragments thereof; and (b) detecting differences in sequence or amount between the target region and the control target region, as an indication of the disease or disorder. Preferably, the disease or disorder is selected from the group consisting of immune-related diseases and disorders, organ transplantation, myocardial infarction, cardiovascular disease, stroke, renal failure, oxidative stress-related neurodegenerative disorders, and cancer. Immune-related diseases and disorders include, but are not limited to, those discussed previously.

[0105] The term "comparing" as used herein refers to identifying discrepancies between the nucleic acid target region isolated from a sample, and the control nucleic acid target region. The discrepancies can be in the nucleotide sequences, *e.g.* insertions, deletions, or point mutations, or in the amount of a given nucleotide sequence. Methods to determine these discrepancies in sequences are well-known to one of ordinary skill in the art. The "control" nucleic acid target region refers to the sequence or amount of the sequence found in normal cells, *e.g.* cells that are not diseased as discussed previously.

[0106] The invention has been described broadly and generically herein. Each of

the narrower species and subgeneric groupings falling within the generic disclosure also form part of the invention. This includes the generic description of the invention with a proviso or negative limitation removing any subject matter from the genus, regardless of whether or not the excised material is specifically recited herein. For example, in some instances the nucleotide sequence of the ZC4 kinase polypeptide may not be part of a preferred embodiment.

[0107] The summary of the invention described above is not limiting and other features and advantages of the invention will be apparent from the following detailed description of the invention, and from the claims.

BRIEF DESCRIPTION OF THE FIGURES

[0108] Figures 1A, 1B and 1C show a multiple sequence alignment of the amino acid sequences (SEQ ID NOS 84-85, 5-7, respectively, in order of appearance) of the STE20-STE20 family kinases.

[0109] Figures 2A and 2B show a multiple sequence alignment of the amino acid sequences (SEQ ID NOS 84, 86-87 & 8, respectively, in order of appearance) of the STE20-STLK5 family kinases.

[0110] Figures 3A, 3B, 3C, 3D, 3E, 3F and 3G show a multiple sequence alignment of the amino acid sequences (SEQ ID NOS 88-89, 13-16, respectively, in order of appearance) of STE20-ZC family kinases.

[0111] Figures 4A, 4B and 4C show a pairwise sequence (SEQ ID NOS 91 & 18, respectively, in order of appearance) alignment of STE20-KHS family kinases.

[0112] Figures 5A, 5B, 5C and 5D show a multiple sequence alignment of the amino acid sequences (SEQ ID NOS 90, 22, 24 & 151 respectively, in order of appearance) of STE20-SULU family kinases.

[0113] Figures 6A, 6B and 6C show a pairwise sequence (SEQ ID NOS 92 & 26, respectively, in order of appearance) alignment of STE20-GEK family kinases.

[0114] Figures 7A, 7B and 7C show a multiple sequence alignment of the amino acid sequences (SEQ ID NOS 93-95, 29-30 respectively, in order of appearance) of STE20-PAK family kinases.

[0115] Figures 8A, 8B, 8C, 8D, 8E, 8F and 8G show the amino acid sequences of

human STLK2(SEQ ID NO:5), human STLK3(SEQ ID NO:6), human STLK4(SEQ ID NO:7), human STLK5(SEQ ID NO:8), human ZC1(SEQ ID NO:13), human ZC2(SEQ ID NO:14), human ZC3(SEQ ID NO:15), human ZC4(SEQ ID NO:16), human KHS2(SEQ ID NO:18), human SULU1(SEQ ID NO:22), human SULU3(SEQ ID NO:23), murine SULU3(SEQ ID NO:24), human GEK2(SEQ ID NO:26), human PAK4(SEQ ID NO:29), and human PAK5(SEQ ID NO:30).

[0116] Figures 9A, 9B, 9C, 9D, 9E, 9F, 9G, 9H, 9I, 9J, 9K, 9L, 9M, 9N, 9O, 9P, 9Q, 9R, 9S, 9T, 9U and 9V show the nucleic acid sequences of human STLK2(SEQ ID NO:1), human STLK3(SEQ ID NO:2), human STLK4(SEQ ID NO:3), human STLK5(SEQ ID NO:4), human ZC1(SEQ ID NO:9), human ZC2(SEQ ID NO:10), human ZC3(SEQ ID NO:11), human ZC4(SEQ ID NO:12), human KHS2(SEQ ID NO:17), human SULU1(SEQ ID NO:19), human SULU3(SEQ ID NO:20), murine SULU3(SEQ ID NO:21), human GEK2(SEQ ID NO:25), human PAK4(SEQ ID NO:27), and human PAK5(SEQ ID NO:28).

[0117] Figures 10A, 10B and 10C show the full-length amino acid sequences of human STLK5 (SEQ ID NO: 97), human PAK5 (SEQ ID NO:103), and human ZC4 (SEQ ID NO:105), as well as the partial amino acid sequences of human full-length STLK6 (SEQ ID NO: 99) and human STLK7 (SEQ ID NO: 101) and human GEK2 (SEQ ID NO: 107).

[0118] Figures 11A, 11B, 11C, 11D, 11E, 11F, 11G and 11H show the full-length nucleic acid sequences of human STLK5 (SEQ ID NO:96), human PAK5 (SEQ ID NO:102), and human ZC4 (SEQ ID NO:104), as well as the partial nucleic acid sequences of human STLK6 (SEQ ID NO: 98) and human STLK7 (SEQ ID NO: 100) and human GEK2 (SEQ ID NO: 106).

[0119] Figures 12A and 12B show a multiple sequence alignment among human SPAK (SEQ ID NO: 153), human STLK6 (SEQ ID NO: 99), human STLK7 (SEQ ID NO: 101) and full-length human STLK5 (SEQ ID NO: 152).

[0120] Figures 13A, 13B and 13C show a multiple sequence alignment among human PAK1 (SEQ ID NO: 93), human PAK4 (SEQ ID NO: 29) and human PAK5 (SEQ ID NO: 103).

[0121] Figures 14A, 14B and 14C show a pair-wise sequence alignment between

human ZC1 (SEQ ID NO: 15) and human ZC4 (SEQ ID NO: 105).

[0122] Figures 15A, 15B and 15C show a pair-wise sequence alignment between LOK1 (SEQ ID NO: 154) and full-length GEK2 (SEQ ID NO: 155).

DETAILED DESCRIPTION OF THE INVENTION

[0123] The present invention relates in part to kinase polypeptides, nucleic acids encoding such polypeptides, cells containing such nucleic acids, antibodies to such polypeptides, assays utilizing such polypeptides, and methods relating to all of the foregoing. The present invention is based upon the isolation and characterization of new kinase polypeptides. The polypeptides and nucleic acids may be produced using well-known and standard synthesis techniques when given the sequences presented herein.

[0124] The recent elucidation of the DNA sequence of *Saccharomyces cerevesiae* has provided the first complete example of the genetic information contained in a simple eukaryotic organism. Analysis of this yeast genome revealed that it contains at least 113 protein kinases. These kinases were further subdivided into several structurally related groups. One of these newly defined groups was termed the STE20-family to represent its founding member STE20, which is a protein kinase involved in the yeast pheromone response pathway that initiates a protein kinase cascade in response to a G-protein mediated signal. *S. cerevesiae* has two additional members of this family, CLA4, and YOL113W (HRA655).

[0125] Several mammalian homologues have recently been identified that belong to the STE20-family, including SOK-1 (human STE20), GC-kinase, KHS, HPK1, NIK, SLK, GEK, PAK1, PAK65, MST1, and CDC7. Furthermore, the *Drosophila* and the *C. elegans* genome efforts have identified additional protein kinases which belong to the STE20-family, yet have structurally unique extracatalytic domains, including ZC504.4 and SULU kinases from *C. elegans*, and NINAC of *Drosophila*.

[0126] STE20-related protein kinases have been implicated as regulating a variety of cellular responses, including response to growth factors or cytokines, oxidative-, UV-, or irradiation-related stress pathways, inflammatory signals (*i.e.*, TNF α), apoptotic stimuli (*i.e.*, Fas), T and B cell costimulation, the control of cytoskeletal architecture, and cellular transformation. Typically, the STE20-related kinases serve as upstream regulators of

MAPK cascades. Examples include: HPK1, a protein-serine/ threonine kinase (STK) that possesses a STE20-like kinase domain that activates a protein kinase pathway leading to the stress-activated protein kinase SAPK/JNK; PAK1, an STK with an upstream CDC42-binding domain that interacts with Rac and plays a role in cellular transformation through the Ras-MAPK pathway; and murine NIK, which interacts with upstream receptor tyrosine kinases and connects with downstream STE11-family kinases.

[0127] The STE20-kinases possess a variety of non-catalytic domains that are believed to interact with upstream regulators. Examples include proline-rich domains for interaction with SH3-containing proteins, or specific domains for interaction with Rac, Rho, and Rab small G-proteins. These interactions may provide a mechanism for cross-talk between distinct biochemical pathways in response to external stimuli such as the activation of a variety of cell surface receptors, including tyrosine kinases, cytokine receptors, TNF receptor, Fas, T cell receptors, CD28, or CD40.

I. The Nucleic Acids of the Invention

[0128] Included within the scope of this invention are the functional equivalents of the herein-described isolated nucleic acid molecules. The degeneracy of the genetic code permits substitution of certain codons by other codons that specify the same amino acid and hence would give rise to the same protein. The nucleic acid sequence can vary substantially since, with the exception of methionine and tryptophan, the known amino acids can be coded for by more than one codon. Thus, portions or all of the kinase genes of the invention could be synthesized to give a nucleic acid sequence significantly different from that shown in SEQ ID NO:1, SEQ ID NO:2, SEQ ID NO:3, SEQ ID NO:9, SEQ ID NO:10, SEQ ID NO:11, SEQ ID NO:17, SEQ ID NO:19, SEQ ID NO:20, SEQ ID NO:21, SEQ ID NO:27, SEQ ID NO:96, SEQ ID NO:98, SEQ ID NO:100, SEQ ID NO:102, SEQ ID NO:104, and SEQ ID NO:106. The encoded amino acid sequence thereof would, however, be preserved.

[0129] In addition, the nucleic acid sequence may comprise a nucleotide sequence which results from the addition, deletion or substitution of at least one nucleotide to the 5'-end and/or the 3'-end of the nucleic acid formula shown in SEQ ID NO:1, SEQ ID NO:2, SEQ ID NO:3, SEQ ID NO:9, SEQ ID NO:10, SEQ ID NO:11, SEQ ID NO:17, SEQ ID

NO:19, SEQ ID NO:20, SEQ ID NO:21, SEQ ID NO:27, SEQ ID NO:96, SEQ ID NO:98, SEQ ID NO:100, SEQ ID NO:102, SEQ ID NO:104, or SEQ ID NO:106, or a derivative thereof. Any nucleotide or polynucleotide may be used in this regard, provided that its addition, deletion or substitution does not alter the amino acid sequence of SEQ ID NO:5, SEQ ID NO:6, SEQ ID NO:7, SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, SEQ ID NO:18, SEQ ID NO:22, SEQ ID NO:23, SEQ ID NO:24, SEQ ID NO:29, SEQ ID NO:97, SEQ ID NO:99, SEQ ID NO:101, SEQ ID NO:103, SEQ ID NO:105, or SEQ ID NO:107, which is encoded by the nucleotide sequence. For example, the present invention is intended to include any nucleic acid sequence resulting from the addition of ATG as an initiation codon at the 5'-end of the inventive nucleic acid sequence or its derivative, or from the addition of TTA, TAG or TGA as a termination codon at the 3'-end of the inventive nucleotide sequence or its derivative. Moreover, the nucleic acid molecule of the present invention may, as necessary, have restriction endonuclease recognition sites added to its 5'-end and/or 3'-end.

[0130] Such functional alterations of a given nucleic acid sequence afford an opportunity to promote secretion and/or processing of heterologous proteins encoded by foreign nucleic acid sequences fused thereto. All variations of the nucleotide sequence of the kinase genes of the invention and fragments thereof permitted by the genetic code are, therefore, included in this invention.

[0131] Further, it is possible to delete codons or to substitute one or more codons with codons other than degenerate codons to produce a structurally modified polypeptide, but one which has substantially the same utility or activity as the polypeptide produced by the unmodified nucleic acid molecule. As recognized in the art, the two polypeptides are functionally equivalent, as are the two nucleic acid molecules that give rise to their production, even though the differences between the nucleic acid molecules are not related to the degeneracy of the genetic code.

Mammalian STLK2

[0132] The full-length human STLK2 cDNA (SEQ ID NO:1) is 3268 bp long and consists of a 1248 bp open reading frame (ORF) flanked by a 181 bp 5' untranslated region (UTR; 1-181) and a 1784 bp 3' UTR (1433-3216) that is followed by a 52

nucleotide polyadenylated region. A polyadenylation signal (AATAAA) is found at positions (3193-3198). The sequence flanking the first ATG conforms to the Kozak consensus (Kozak, M., Nucleic Acids Res. 15, 8125-8148 (1987)) for an initiating methionine, and is believed to be the translational start site for STLK2. Furthermore, human STLK2 and the related SOK-1 and MST3 proteins conserve the amino acid sequence immediately following this presumed initiating methionine.

[0133] Several EST fragments span the complete STLK2 sequence with AA191319 at the 5' end and W16504 at the 3' end.

Mammalian STLK3

[0134] The partial human STLK3 cDNA (SEQ ID NO:2) is 3030 bp long and consists of a 1548 bp ORF flanked by a 1476 bp 3' UTR (1550-3025) and a 5 nucleotide polyadenylated region. A potential polyadenylation signal (AATAAA) begins at position 3004. Since the coding region is open throughout the 5' extent of this sequence, this is apparently a partial cDNA clone lacking the N-terminal start methionine.

[0135] Multiple EST fragments span the complete STLK3 sequence with AA278967 at the 5' end and AA628477 and others at the 3' end.

Mammalian STLK4

[0136] The partial human STLK4 cDNA (SEQ ID NO:3) is 3857 bp long and consists of a 1242 bp ORF flanked by a 2596 bp 3' UTR (1244-3839) and an 18 nucleotide polyadenylated region. A potential polyadenylation signal (AATAAA) is found at positions 2181-3822. Since the coding region is open throughout the 5' extent of this sequence, this is apparently a partial cDNA clone lacking the N-terminal start methionine.

A near full-length murine STLK4 cDNA is represented in the 1773 bp EST AA117438. It extends an additional 21 nucleotides 5' of the human STLK4 consensus, but since its coding region is open throughout the 5' extent of the sequence, this is also apparently a partial cDNA clone lacking the N-terminal start methionine.

[0137] Several EST fragments span the complete STLK3 sequence with AA297759 at the 5' end and AA100484 and others at the 3' end.

Mammalian STLK5

[0138] The full-length human STLK5 cDNA (SEQ ID NO:96) is 2110 bp long and consists of a 1119 bp ORF flanked by a 229 bp 5' UTR and a 762 bp 3' UTR. The sequence flanking the first ATG conforms to the Kozak consensus (supra) for an initiating methionine, and is believed to be the translational start site for STLK5. Several EST fragments span the complete STLK5 sequence with AA297059 and F07734 at the 5' end, and R46686 and F03423 and others at the 3' end.

Mammalian STLK6

[0139] The full-length human STLK6 cDNA (SEQ ID NO:98) is 2,001 bp long and consists of a 1,254 bp ORF flanked by a 75 bp 5' UTR and a 673 bp 3' UTR. The sequence flanking the first ATG conforms to the Kozak consensus (supra) for an initiating methionine, and is believed to be the translational start site for STLK6.

Mammalian STLK7

[0140] The partial human STLK7 cDNA (SEQ ID NO:100) is 311 bp long and consists of a 309 bp ORF. Since the coding region is open throughout both the 5' and 3' extent of this sequence, this is apparently a partial cDNA clone lacking the N-terminal start methionine and C-terminal stop codon.

Mammalian ZC1

[0141] The full-length human ZC1 cDNA (SEQ ID NO:9) is 3798 bp long and consists of a 3717 bp ORF (7-3723) flanked by a 6 bp 5' UTR and a 75 bp (3724-3798) 3' UTR. No polyadenylation signal (AATAAA) or polyadenylated region are present in the 3'UTR. The sequence flanking the first ATG conforms to the Kozak consensus for an initiating methionine, and is believed to be the translational start site for human ZC1.

[0142] Multiple EST fragments (W81656) match the 3' end of the human ZC1 gene, but at the time of filing, the inventors believe that none exist in GenBank or the EST database that match its 5' end.

Mammalian ZC2

[0143] The partial human ZC2 cDNA (SEQ ID NO:10) is 4055 bp long and consists of a 3891 bp ORF (1-3891) and a 164 bp (3892-4055) 3' UTR. Since the coding region is open throughout the 5' extent of this sequence, this is apparently a partial cDNA clone lacking the N-terminal start methionine. No polyadenylation signal (AATAAA) or polyadenylated region are present in the 3'UTR.

[0144] Multiple EST fragments (R51245) match the 3' end of the human ZC2 gene, but at the time of filing, the inventors believe that none exist in GenBank or the EST database that match its 5' end.

Mammalian ZC3

[0145] The partial human ZC3 cDNA (SEQ ID NO:11) is 4133 bp long and consists of a 3978 bp ORF (1-3978) and a 152 bp (3979-4133) 3'UTR region. Since the coding region is open throughout the 5' extent of this sequence, this is apparently a partial cDNA clone lacking the N-terminal start methionine. No polyadenylation signal (AATAAA) or polyadenylated region are present in the 3'UTR.

[0146] Multiple EST fragments (R54563) match the 3'end of the human ZC3 gene, but at the time of filing, the inventors believe that none exist in GenBank or the EST database that match its 5' end.

Mammalian ZC4

[0147] The full-length human ZC4 cDNA (SEQ ID NO:104) is 3,684 bp long and was originally assembled from X chromosome genomic DNA sequence.

[0148] Multiple EST fragments (R98571) match the 3'end of the human ZC4 gene, but at the time of filing, the inventors believe that none exist in GenBank or the EST database that match its 5' end. ZC4 gene is also contained within the human genomic clone Z83850.

Mammalian KHS2

[0149] The full-length human KHS2 cDNA (SEQ ID NO:17) is 4023 bp long and consists of a 2682 bp ORF (6-2687) flanked by a 5 bp (1-5) 5'UTR and a 1336 bp (2688-4023) 3' UTR. A potential polyadenylation signal (AATAAA) is found at positions 4008-

4013. No polyadenylated region is present in the 3'UTR. The sequence flanking the first ATG conforms to the Kozak consensus for an initiating methionine, and is believed to be the translational start site for human KHS2.

[0150] Multiple EST fragments match the 5' end (AA446022) as well as the 3' end (R37625) of the human KHS2 gene.

Mammalian SULU1

[0151] The full-length human SULU1 cDNA (SEQ ID NO:19) is 4177 bp long and consists of a 2694 bp ORF (415-3108) flanked by a 414 bp (1-414) 5'UTR and a 1069 bp (3109-4177) 3' UTR followed by a 19 nucleotide polydenylated region. A potential polyadenylation signal (AATAAA) is found at positions 4164-4169. The sequence flanking the first ATG conforms to the Kozak consensus for an initiating methionine, and is believed to be the translational start site for human SULU1.

[0152] Multiple EST fragments match the 5' end (N27153) as well as the 3' end (R90908) of the human SULU1 gene.

Mammalian (Murine) SULU3

[0153] The partial murine SULU3 cDNA (SEQ ID NO:21) is 2249 bp long and consists of a 2244 bp ORF (6-2249) flanked by a 5 bp (1-5) 5'UTR. The sequence flanking the first ATG conforms to the Kozak consensus for an initiating methionine, and is believed to be the translational start site for murine SULU3. The 3' end of the murine SULU3 cDNA shares 90% DNA sequence identity over 1620 nucleotides with human SULU3, suggesting that these two genes are functional orthologues.

[0154] One EST fragment (AA446022) matches the 3' end of the partial murine SULU3 gene, but at the time of filing, the inventors believe that none exist in GenBank or the EST database that match its 5' end.

Mammalian (Human) SULU3

[0155] The partial human SULU3 cDNA (SEQ ID NO:20) is 3824 bp long and consists of a 2358 bp ORF (2-2359) flanked by a 1465 bp (2360-3824) 3'UTR followed by a 19 nucleotide polydenylated region. A potential polyadenylation signal (AATAAA) is

found at positions 2602-2607. Since the coding region is open throughout the 5' extent of this sequence, this is apparently a partial cDNA clone lacking the N-terminal start methionine. The 5' end of the human SULU3 cDNA shares 90% DNA sequence identity over 1620 nucleotides with murine SULU3, suggesting that these two genes are functional orthologues.

[0156] Multiple EST fragments (R02283) match the 3' end of the human SULU3 gene, but at the time of filing, the inventors believe that none exist in GenBank or the EST database that match its 5' end.

Mammalian GEK2

[0157] The full-length human GEK2 cDNA (SEQ ID NO:106) is 2962 bp long and consists of a 2737 bp ORF (59-2795) flanked by a 58 bp (1-58) 5'UTR. The sequence flanking the first ATG conforms to the Kozak consensus for an initiating methionine, and is believed to be the translational start site for human GEK2.

[0158] Multiple EST fragments (AA465671) match the 5' end, but at the time of filing, the inventors believe that only one (AA380492) matches the 3' end of the human GEK2 gene.

Mammalian PAK4

[0159] The full-length human PAK4 cDNA (SEQ ID NO:27) is 3604 bp long and consists of a 2043 bp ORF (143-2185) flanked by a 142 bp (1-142) 5'UTR and a 1419 3' UTR followed by a 22 nucleotide polydenylated region. A potential polyadenylation signal (AATTAAA) is found at positions 3582-3588. The sequence flanking the first ATG conforms to the Kozak consensus for an initiating methionine, and is believed to be the translational start site for human PAK4.

[0160] Multiple EST fragments (AA535791) match the 3' end of the human PAK4 gene, but at the time of filing, the inventors believe that none exist in GenBank or the EST database that match its 5' end.

Mammalian PAK5

[0161] The full-length human PAK5 cDNA (SEQ ID NO:102) is 2806 bp long and

consists of a 1773 bp ORF flanked by a 201 bp 5' UTR and a 833 bp 3' UTR. The sequence flanking the first ATG conforms to the Kozak consensus (*supra*) for an initiating methionine, and is believed to be the translational start site for PAK5.

[0162] Multiple EST fragments (AA442867) match the 3' end of the human PAK5 gene, but at the time of filing, the inventors believe that none exist in GenBank or the EST database that match its 5' end.

II. Nucleic Acid Probes, Methods, and Kits for Detection of STE20-Related Kinases.

[0163] A nucleic acid probe of the present invention may be used to probe an appropriate chromosomal or cDNA library by usual hybridization methods to obtain other nucleic acid molecules of the present invention. A chromosomal DNA or cDNA library may be prepared from appropriate cells according to recognized methods in the art (*cf.* "Molecular Cloning: A Laboratory Manual", second edition, Cold Spring Harbor Laboratory, Sambrook, Fritsch, & Maniatis, eds., 1989).

[0164] In the alternative, chemical synthesis can be carried out in order to obtain nucleic acid probes having nucleotide sequences which correspond to N-terminal and C-terminal portions of the amino acid sequence of the polypeptide of interest. The synthesized nucleic acid probes may be used as primers in a polymerase chain reaction (PCR) carried out in accordance with recognized PCR techniques, essentially according to PCR Protocols, "A Guide to Methods and Applications", Academic Press, Michael, *et al.*, eds., 1990, utilizing the appropriate chromosomal or cDNA library to obtain the fragment of the present invention.

[0165] One skilled in the art can readily design such probes based on the sequence disclosed herein using methods of computer alignment and sequence analysis known in the art ("Molecular Cloning: A Laboratory Manual", 1989, *supra*). The hybridization probes of the present invention can be labeled by standard labeling techniques such as with a radiolabel, enzyme label, fluorescent label, biotin-avidin label, chemiluminescence, and the like. After hybridization, the probes may be visualized using known methods.

[0166] The nucleic acid probes of the present invention include RNA, as well as DNA probes, such probes being generated using techniques known in the art. The nucleic acid probe may be immobilized on a solid support. Examples of such solid supports

include, but are not limited to, plastics such as polycarbonate, complex carbohydrates such as agarose and sepharose, and acrylic resins, such as polyacrylamide and latex beads. Techniques for coupling nucleic acid probes to such solid supports are well known in the art.

[0167] The test samples suitable for nucleic acid probing methods of the present invention include, for example, cells or nucleic acid extracts of cells, or biological fluids. The samples used in the above-described methods will vary based on the assay format, the detection method and the nature of the tissues, cells or extracts to be assayed. Methods for preparing nucleic acid extracts of cells are well known in the art and can be readily adapted in order to obtain a sample which is compatible with the method utilized.

[0168] One method of detecting the presence of nucleic acids of the invention in a sample comprises (a) contacting said sample with the above-described nucleic acid probe under conditions such that hybridization occurs, and (b) detecting the presence of said probe bound to said nucleic acid molecule. One skilled in the art would select the nucleic acid probe according to techniques known in the art as described above. Samples to be tested include but should not be limited to RNA samples of human tissue.

[0169] A kit for detecting the presence of nucleic acids of the invention in a sample comprises at least one container means having disposed therein the above-described nucleic acid probe. The kit may further comprise other containers comprising one or more of the following: wash reagents and reagents capable of detecting the presence of bound nucleic acid probe. Examples of detection reagents include, but are not limited to radiolabelled probes, enzymatic labeled probes (horseradish peroxidase, alkaline phosphatase), and affinity labeled probes (biotin, avidin, or streptavidin).

[0170] In detail, a compartmentalized kit includes any kit in which reagents are contained in separate containers. Such containers include small glass containers, plastic containers or strips of plastic or paper. Such containers allow the efficient transfer of reagents from one compartment to another compartment such that the samples and reagents are not cross-contaminated and the agents or solutions of each container can be added in a quantitative fashion from one compartment to another. Such containers will include a container which will accept the test sample, a container which contains the probe or primers used in the assay, containers which contain wash reagents (such as phosphate

buffered saline, Tris-buffers, and the like), and containers which contain the reagents used to detect the hybridized probe, bound antibody, amplified product, or the like. One skilled in the art will readily recognize that the nucleic acid probes described in the present invention can readily be incorporated into one of the established kit formats which are well known in the art.

III. DNA Constructs Comprising a STE20-Related Nucleic Acid Molecule and Cells Containing These Constructs.

[0171] The present invention also relates to a recombinant DNA molecule comprising, 5' to 3', a promoter effective to initiate transcription in a host cell and the above-described nucleic acid molecules. In addition, the present invention relates to a recombinant DNA molecule comprising a vector and an above-described nucleic acid molecule. The present invention also relates to a nucleic acid molecule comprising a transcriptional region functional in a cell, a sequence complementary to an RNA sequence encoding an amino acid sequence corresponding to the above-described polypeptide, and a transcriptional termination region functional in said cell. The above-described molecules may be isolated and/or purified DNA molecules.

[0172] The present invention also relates to a cell or organism that contains an above-described nucleic acid molecule and thereby is capable of expressing a polypeptide. The polypeptide may be purified from cells which have been altered to express the polypeptide. A cell is said to be "altered to express a desired polypeptide" when the cell, through genetic manipulation, is made to produce a protein which it normally does not produce or which the cell normally produces at lower levels. One skilled in the art can readily adapt procedures for introducing and expressing either genomic, cDNA, or synthetic sequences into either eukaryotic or prokaryotic cells.

[0173] A nucleic acid molecule, such as DNA, is said to be "capable of expressing" a polypeptide if it contains nucleotide sequences which contain transcriptional and translational regulatory information and such sequences are "operably linked" to nucleotide sequences which encode the polypeptide. An operable linkage is a linkage in which the regulatory DNA sequences and the DNA sequence sought to be expressed are connected in such a way as to permit gene sequence expression. The precise nature of the

regulatory regions needed for gene sequence expression may vary from organism to organism, but shall in general include a promoter region which, in prokaryotes, contains both the promoter (which directs the initiation of RNA transcription) as well as the DNA sequences which, when transcribed into RNA, will signal synthesis initiation. Such regions will normally include those 5'-non-coding sequences involved with initiation of transcription and translation, such as the TATA box, capping sequence, CAAT sequence, and the like.

[0174] If desired, the non-coding region 3' to the sequence encoding a kinase of the invention may be obtained by the above-described methods. This region may be retained for its transcriptional termination regulatory sequences, such as termination and polyadenylation. Thus, by retaining the 3'-region naturally contiguous to the DNA sequence encoding a kinase of the invention, the transcriptional termination signals may be provided. Where the transcriptional termination signals are not satisfactorily functional in the expression host cell, then a 3' region functional in the host cell may be substituted.

[0175] Two DNA sequences (such as a promoter region sequence and a sequence encoding a kinase of the invention) are said to be operably linked if the nature of the linkage between the two DNA sequences does not (1) result in the introduction of a frame-shift mutation, (2) interfere with the ability of the promoter region sequence to direct the transcription of a gene sequence encoding a kinase of the invention, or (3) interfere with the ability of the gene sequence of a kinase of the invention to be transcribed by the promoter region sequence. Thus, a promoter region would be operably linked to a DNA sequence if the promoter were capable of effecting transcription of that DNA sequence. Thus, to express a gene encoding a kinase of the invention, transcriptional and translational signals recognized by an appropriate host are necessary.

[0176] The present invention encompasses the expression of a gene encoding a kinase of the invention (or a functional derivative thereof) in either prokaryotic or eukaryotic cells. Prokaryotic hosts are, generally, very efficient and convenient for the production of recombinant proteins and are, therefore, one type of preferred expression system for kinases of the invention. Prokaryotes most frequently are represented by various strains of *E. coli*. However, other microbial strains may also be used, including other bacterial strains.

[0177] In prokaryotic systems, plasmid vectors that contain replication sites and control sequences derived from a species compatible with the host may be used. Examples of suitable plasmid vectors may include pBR322, pUC118, pUC119 and the like; suitable phage or bacteriophage vectors may include γ gt10, γ gt11 and the like; and suitable virus vectors may include pMAM-neo, pKRC and the like. Preferably, the selected vector of the present invention has the capacity to replicate in the selected host cell.

[0178] Recognized prokaryotic hosts include bacteria such as *E. coli*, *Bacillus*, *Streptomyces*, *Pseudomonas*, *Salmonella*, *Serratia*, and the like. However, under such conditions, the polypeptide will not be glycosylated. The prokaryotic host must be compatible with the replicon and control sequences in the expression plasmid.

[0179] To express a kinase of the invention (or a functional derivative thereof) in a prokaryotic cell, it is necessary to operably link the sequence encoding the kinase of the invention to a functional prokaryotic promoter. Such promoters may be either constitutive or, more preferably, regulatable (*i.e.*, inducible or derepressible). Examples of constitutive promoters include the *int* promoter of bacteriophage λ , the *bla* promoter of the β -lactamase gene sequence of pBR322, and the *cat* promoter of the chloramphenicol acetyl transferase gene sequence of pPR325, and the like. Examples of inducible prokaryotic promoters include the major right and left promoters of bacteriophage λ (P_L and P_R), the *trp*, *recA*, *lacZ*, *lacI*, and *gal* promoters of *E. coli*, the α -amylase (Ulmanen *et al.*, J. Bacteriol. 162:176-182, 1985) and the ϕ -28-specific promoters of *B. subtilis* (Gilman *et al.*, Gene Sequence 32:11-20, 1984), the promoters of the bacteriophages of *Bacillus* (Gryczan, In: The Molecular Biology of the Bacilli, Academic Press, Inc., NY, 1982), and *Streptomyces* promoters (Ward *et al.*, Mol. Gen. Genet. 203:468-478, 1986). Prokaryotic promoters are reviewed by Glick (Ind. Microbiot. 1:277-282, 1987), Cenatiempo (Biochimie 68:505-516, 1986), and Gottesman (Ann. Rev. Genet. 18:415-442, 1984).

[0180] Proper expression in a prokaryotic cell also requires the presence of a ribosome-binding site upstream of the gene sequence-encoding sequence. Such ribosome-binding sites are disclosed, for example, by Gold *et al.* (Ann. Rev. Microbiol. 35:365-404, 1981). The selection of control sequences, expression vectors, transformation methods, and the like, are dependent on the type of host cell used to express the gene. As used herein, "cell", "cell line", and "cell culture" may be used interchangeably and all such

designations include progeny. Thus, the words "transformants" or "transformed cells" include the primary subject cell and cultures derived therefrom, without regard to the number of transfers. It is also understood that all progeny may not be precisely identical in DNA content, due to deliberate or inadvertent mutations. However, as defined, mutant progeny have the same functionality as that of the originally transformed cell.

[0181] Host cells which may be used in the expression systems of the present invention are not strictly limited, provided that they are suitable for use in the expression of the kinase polypeptide of interest. Suitable hosts may often include eukaryotic cells. Preferred eukaryotic hosts include, for example, yeast, fungi, insect cells, mammalian cells either *in vivo*, or in tissue culture. Mammalian cells which may be useful as hosts include HeLa cells, cells of fibroblast origin such as VERO or CHO-K1, or cells of lymphoid origin and their derivatives. Preferred mammalian host cells include SP2/0 and J558L, as well as neuroblastoma cell lines such as IMR 332, which may provide better capacities for correct post-translational processing.

[0182] In addition, plant cells are also available as hosts, and control sequences compatible with plant cells are available, such as the cauliflower mosaic virus 35S and 19S, and nopaline synthase promoter and polyadenylation signal sequences. Another preferred host is an insect cell, for example the *Drosophila* larvae. Using insect cells as hosts, the *Drosophila* alcohol dehydrogenase promoter can be used (Rubin, Science 240:1453-1459, 1988). Alternatively, baculovirus vectors can be engineered to express large amounts of kinases of the invention in insect cells (Jasny, Science 238:1653, 1987; Miller *et al.*, In: Genetic Engineering, Vol. 8, Plenum, Setlow *et al.*, eds., pp. 277-297, 1986).

[0183] Any of a series of yeast expression systems can be utilized which incorporate promoter and termination elements from the actively expressed sequences coding for glycolytic enzymes that are produced in large quantities when yeast are grown in mediums rich in glucose. Known glycolytic gene sequences can also provide very efficient transcriptional control signals. Yeast provides substantial advantages in that it can also carry out post-translational modifications. A number of recombinant DNA strategies exist utilizing strong promoter sequences and high copy number plasmids which can be utilized for production of the desired proteins in yeast. Yeast recognizes leader

sequences on cloned mammalian genes and secretes peptides bearing leader sequences (*i.e.*, pre-peptides). Several possible vector systems are available for the expression of kinases of the invention in a mammalian host.

[0184] A wide variety of transcriptional and translational regulatory sequences may be employed, depending upon the nature of the host. The transcriptional and translational regulatory signals may be derived from viral sources, such as adenovirus, bovine papilloma virus, cytomegalovirus, simian virus, or the like, where the regulatory signals are associated with a particular gene sequence which has a high level of expression. Alternatively, promoters from mammalian expression products, such as actin, collagen, myosin, and the like, may be employed. Transcriptional initiation regulatory signals may be selected which allow for repression or activation, so that expression of the gene sequences can be modulated. Of interest are regulatory signals which are temperature-sensitive so that by varying the temperature, expression can be repressed or initiated, or are subject to chemical (such as metabolite) regulation.

[0185] Expression of kinases of the invention in eukaryotic hosts requires the use of eukaryotic regulatory regions. Such regions will, in general, include a promoter region sufficient to direct the initiation of RNA synthesis. Preferred eukaryotic promoters include, for example, the promoter of the mouse metallothionein I gene sequence (Hamer *et al.*, J. Mol. Appl. Gen. 1:273-288, 1982); the TK promoter of Herpes virus (McKnight, Cell 31:355-365, 1982); the SV40 early promoter (Benoist *et al.*, Nature (London) 290:304-31, 1981); and the yeast gal4 gene sequence promoter (Johnston *et al.*, Proc. Natl. Acad. Sci. (USA) 79:6971-6975, 1982; Silver *et al.*, Proc. Natl. Acad. Sci. (USA) 81:5951-5955, 1984).

[0186] Translation of eukaryotic mRNA is initiated at the codon which encodes the first methionine. For this reason, it is preferable to ensure that the linkage between a eukaryotic promoter and a DNA sequence which encodes a kinase of the invention (or a functional derivative thereof) does not contain any intervening codons which are capable of encoding a methionine (*i.e.*, AUG). The presence of such codons results either in the formation of a fusion protein (if the AUG codon is in the same reading frame as the kinase of the invention coding sequence) or a frame-shift mutation (if the AUG codon is not in the same reading frame as the kinase of the invention coding sequence).

[0187] A nucleic acid molecule encoding a kinase of the invention and an operably linked promoter may be introduced into a recipient prokaryotic or eukaryotic cell either as a nonreplicating DNA or RNA molecule, which may either be a linear molecule or, more preferably, a closed covalent circular molecule. Since such molecules are incapable of autonomous replication, the expression of the gene may occur through the transient expression of the introduced sequence. Alternatively, permanent expression may occur through the integration of the introduced DNA sequence into the host chromosome.

[0188] A vector may be employed which is capable of integrating the desired gene sequences into the host cell chromosome. Cells which have stably integrated the introduced DNA into their chromosomes can be selected by also introducing one or more markers which allow for selection of host cells which contain the expression vector. The marker may provide for prototrophy to an auxotrophic host, biocide resistance, *e.g.*, antibiotics, or heavy metals, such as copper, or the like. The selectable marker gene sequence can either be directly linked to the DNA gene sequences to be expressed, or introduced into the same cell by co-transfection. Additional elements may also be needed for optimal synthesis of mRNA. These elements may include splice signals, as well as transcription promoters, enhancers, and termination signals. cDNA expression vectors incorporating such elements include those described by Okayama (Mol. Cell. Biol. 3:280-, 1983).

[0189] The introduced nucleic acid molecule can be incorporated into a plasmid or viral vector capable of autonomous replication in the recipient host. Any of a wide variety of vectors may be employed for this purpose. Factors of importance in selecting a particular plasmid or viral vector include: the ease with which recipient cells that contain the vector may be recognized and selected from those recipient cells which do not contain the vector; the number of copies of the vector which are desired in a particular host; and whether it is desirable to be able to "shuttle" the vector between host cells of different species.

[0190] Preferred prokaryotic vectors include plasmids such as those capable of replication in *E. coli* (such as, for example, pBR322, ColEI, pSC101, pACYC 184, □VX; "Molecular Cloning: A Laboratory Manual", 1989, *supra*). *Bacillus* plasmids include pC194, pC221, pT127, and the like (Gryczan, In: The Molecular Biology of the Bacilli,

Academic Press, NY, pp. 307-329, 1982). Suitable *Streptomyces* plasmids include p1J101 (Kendall *et al.*, J. Bacteriol. 169:4177-4183, 1987), and streptomyces bacteriophages such as ϕ C31 (Chater *et al.*, In: Sixth International Symposium on Actinomycetales Biology, Akademiai Kiado, Budapest, Hungary, pp. 45-54, 1986). *Pseudomonas* plasmids are reviewed by John *et al.* (Rev. Infect. Dis. 8:693-704, 1986), and Izaki (Jpn. J. Bacteriol. 33:729-742, 1978).

[0191] Preferred eukaryotic plasmids include, for example, BPV, vaccinia, SV40, 2-micron circle, and the like, or their derivatives. Such plasmids are well known in the art (Botstein *et al.*, Miami Wntr. Symp. 19:265-274, 1982; Broach, In: "The Molecular Biology of the Yeast *Saccharomyces*: Life Cycle and Inheritance", Cold Spring Harbor Laboratory, Cold Spring Harbor, NY, p. 445-470, 1981; Broach, Cell 28:203-204, 1982; Bollon *et al.*, J. Clin. Hematol. Oncol. 10:39-48, 1980; Maniatis, In: Cell Biology: A Comprehensive Treatise, Vol. 3, Gene Sequence Expression, Academic Press, NY, pp. 563-608, 1980).

[0192] Once the vector or nucleic acid molecule containing the construct(s) has been prepared for expression, the DNA construct(s) may be introduced into an appropriate host cell by any of a variety of suitable means, *i.e.*, transformation, transfection, conjugation, protoplast fusion, electroporation, particle gun technology, calcium phosphate-precipitation, direct microinjection, and the like. After the introduction of the vector, recipient cells are grown in a selective medium, which selects for the growth of vector-containing cells. Expression of the cloned gene(s) results in the production of a kinase of the invention, or fragments thereof. This can take place in the transformed cells as such, or following the induction of these cells to differentiate (for example, by administration of bromodeoxyuracil to neuroblastoma cells or the like). A variety of incubation conditions can be used to form the peptide of the present invention. The most preferred conditions are those which mimic physiological conditions.

IV. The Proteins of the Invention

[0193] A variety of methodologies known in the art can be utilized to obtain the polypeptides of the present invention. The polypeptides may be purified from tissues or cells that naturally produce the polypeptides. Alternatively, the above-described isolated

nucleic acid fragments could be used to express the kinases of the invention in any organism. The samples of the present invention include cells, protein extracts or membrane extracts of cells, or biological fluids. The samples will vary based on the assay format, the detection method, and the nature of the tissues, cells or extracts used as the sample.

[0194] Any eukaryotic organism can be used as a source for the polypeptides of the invention, as long as the source organism naturally contains such polypeptides. As used herein, "source organism" refers to the original organism from which the amino acid sequence of the subunit is derived, regardless of the organism the subunit is expressed in and ultimately isolated from.

[0195] One skilled in the art can readily follow known methods for isolating proteins in order to obtain the polypeptides free of natural contaminants. These include, but are not limited to: size-exclusion chromatography, HPLC, ion-exchange chromatography, and immuno-affinity chromatography.

Mammalian STLK2

[0196] Analysis of the deduced amino acid sequence predicts STLK2 to be an intracellular serine/threonine kinase, lacking both a signal sequence and transmembrane domain. STLK2 contains a 21 amino acid N-terminal domain, a 253 amino acid catalytic domain with all the motifs characteristic of a serine/threonine kinase, followed by a 142 amino acid C-terminal domain.

[0197] STLK2 is most closely related to human STE20-subfamily kinases, MST3 (GB:AF024636) and SOK-1 (GB:X99325) and a *C. elegans* kinase yk34b11.5 (GB:U53153) sharing 72.7%, 68.7%, and 69.3% amino acid identity, respectively.

[0198] The 21 amino acid N-terminal domain of human STLK2 is 71.4% identical to the N-terminus of MST3 (GB:AF024636). Human STLK2 lacks a glycine residue at position 2, and is therefore unlikely to undergo myristylation. A Smith-Waterman search of the nonredundant protein database does not reveal any significant homologies that might suggest a potential function for this domain.

[0199] The 253 amino acid catalytic domain of human STLK2 is most related to human SOK-1 (X99325), MST3 (GB:AF024636), *C. elegans* yk32b11.5 (GB:U53153),

and STLK3 (SEQ ID NO:6) sharing 88.9%, 87.4%, 78.3%, and 49% amino identity respectively, placing it in the STLK-subfamily of STE20-related kinases. The STLK2 kinase domain displayed lesser homology to other STE20-related kinases including: 55.9% to human MST2 (GB:U26424), 49.2% to human GCK (GB:U07349), 49.2% to human KHS1 (GB:U77129), and 44.2% to human HPK1 (GB:U66464). The activation loop of human STLK2 catalytic domain is identical to that of human SOK-1 and MST3 including the presence of four potential threonine phosphorylation sites that could serve an autoregulatory role on kinase activity.

[0200] The 142 amino acid C-terminal domain of human STLK2 is most related to human SOK-1 (X99325), MST3 (GB:AF024636), and *C. elegans* yk32b11.5 (GB:U53153), sharing 39.9%, 39.9%, and 33.3% amino acid identity, respectively. This C-terminal domain shares some significant amino acid similarity to the C-terminal domains of the related human STLK3 (SEQ ID NO:6) and STLK4 (SEQ ID NO:7).

[0201] The C-terminus of the related human SOK-1 (GB:X99325) kinase has been shown to be inhibitory to the catalytic activity of this kinase (Pombo, C.M., Bonventre, J.V., Molnar, A., Kyriakis, J. and Force, T. EMBO J. 15, 4537-4546 (1996)). Based on the sequence identity between the C-termini of human SOK-1 (GB:X99325) and human STLK2 (39.2%), the C-terminus of human STLK2 may also function as an inhibitory domain for its kinase.

Mammalian STLK3

[0202] The 3030 bp human STLK3 nucleotide sequence of the partial cDNA clone encodes a polypeptide of 516 amino acids (SEQ ID NO:6) with a predicted molecular mass of 56,784 daltons. Analysis of the deduced amino acid sequence predicts STLK3 to be an intracellular serine/threonine kinase, lacking both a signal sequence and transmembrane domain, however the cDNA clone lacks an initiating ATG, so the full extent of its N-terminus is not known. STLK3 contains a 31 amino acid N-terminal domain, a 277 amino acid catalytic domain with all the motifs characteristic of a serine/threonine kinase, followed by a 181 amino acid C-terminal domain containing a 25 amino acid insert and a 27 amino acid tail relative to the sequence of human STLK2.

[0203] STLK3 is most closely related to human STE20-subfamily kinases, STLK4

(SEQ ID. NO:7), MST3 (GB:AF024636), SOK-1 (GB:X99325) and STLK2 (SEQ ID NO:5) sharing 71.1%, 37.6%, 38.1%, and 38.4% amino acid identity respectively.

[0204] The 31 amino acid N-terminal domain of human STLK3 lacked any significant amino acid sequence homologies using a Smith-Waterman search of the nonredundant protein database, other than sequence similarity to proline-alanine repeats.

[0205] The 277 amino acid catalytic domain of human STLK3 is most related to human STLK4 (SEQ ID NO:7), SOK-1 (GB:X99325), MST3 (GB:AF024636), and STLK2 (SEQ ID NO:5) sharing 88.2%, 49.2%, 49%, and 49% amino acid identity, respectively. It also shares strong homology to other STKs from lower organisms including 51.7% to *A. thaliana* (GB: AC002343), 43.1% to *A. thaliana* (GB: Z97336), 42.1% to *A. thaliana* (GB: U96613), and 43.3% to *C. elegans* (GB: U53153). The activation loop of the human STLK3 catalytic domain conserves three potential threonine phosphorylation sites with other members of the STLK-subfamily of STE20-related kinases (human STE20, MST3, STLK2, STLK4) that could serve an autoregulatory role on kinase activity.

[0206] The 181 amino acid C-terminal domain of human STLK3 shares 55.5% amino acid identity to human STLK4 (SEQ ID NO:7), and is 100% identical to a partial human cDNA DCHT (GB:AF017635). The C-terminal domain of human STLK3 contains a 26 amino acid insert relative to human STE20. A similar (87.5% amino acid identity) 26 amino acid insert is also present in human STLK4.

[0207] The 27 amino acid C-terminal tail of human STLK3 shares 77.8% amino acid identity to human STLK4, but is absent from other STLK-family members. This high degree of homology between the C-tail of two STLK-family members suggests they may be involved in an as yet unidentified protein-protein interaction.

[0208] The weak sequence homology between the C-termini of human STLK3 and STE20, suggests it may also function as an inhibitory domain for its kinase.

Mammalian STLK4

[0209] The 3857 bp human STLK4 nucleotide sequence of the partial cDNA clone encodes a polypeptide of 414 amino acids (SEQ ID NO:7) with a predicted molecular mass of 45,451 daltons. Analysis of the deduced amino acid sequence predicts STLK4 to

be an intracellular serine/threonine kinase, lacking both a signal sequence and transmembrane domain, however the cDNA clone lacks an initiating ATG, so the full extent of its N-terminus is not known. The partial STLK4 protein sequence contains a 178 amino acid catalytic domain corresponding to the C-terminal motifs VI-XI of a serine/threonine kinase, followed by a 236 amino acid C-terminal domain containing two inserts of 25 and 41 amino acids each, relative to the sequence of human STLK2.

[0210] STLK4 is most closely related to human STE20-subfamily kinases, STLK3 (SEQ ID NO 6), MST3 (GB:AF024636), STLK2 (SEQ ID NO:5), and SOK-1 (GB:X99325) sharing 71.0%, 46.8%, 43.9%, and 37.7% amino acid identity, respectively.

[0211] The 178 amino acid catalytic domain of human STLK4 is most related to human STLK3 (SEQ ID NO. 7), SOK-1 (GB:X99325), MST3 (GB:AF024636), STLK2 (SEQ ID NO:5), and MST1 (GB:U18297), sharing 88.2%, 54.2%, 54.0%, 53.7 and 45.7% amino acid identity, respectively. It also shares strong homology to other STKs from lower organisms including 56.9% to *A. thaliana* (GB: AC002343), 52.5% to *C. elegans* (GB: U53153), 46.2% to *A. thaliana* (GB: Z97336) and 45.7% to *A. thaliana* (GB: U96613). The activation loop of the human STLK4 catalytic domain conserves three potential threonine phosphorylation sites with other members of the STLK-subfamily of STE20-related kinases (human STE20, MST3, STLK2 and STLK3) that could serve an autoregulatory role on kinase activity.

[0212] The 236 amino acid C-terminal domain of human STLK4 shares 58.1% amino acid identity to both human STLK3 (SEQ ID NO:6) and to a partial human cDNA, DCHT (GB:AF017635). The C-terminal domain of human STLK4 contains a 25 amino acid insert relative to human SOK-1 and shares 87.5% amino acid identity to an insert present in human STLK3.

[0213] The weak sequence homology between the C-termini of human STLK4 and STE20, suggests it may also function as an inhibitory domain for its kinase.

Mammalian STLK5

[0214] The full-length 2110 bp human STLK5 cDNA encodes a polypeptide of 373 amino acids (SEQ ID NO:97) with a predicted molecular mass of 41,700 daltons. Analysis of the deduced amino acid sequence predicts STLK5 to be an intracellular

STE20-subfamily kinase, lacking both a signal sequence and transmembrane domain. STLK5 contains a 10 amino acid N-terminal domain, a 311 amino acid catalytic domain with all the motifs characteristic of a serine/threonine kinase, and a 52 amino acid C-terminal domain.

[0215] STLK5 is most closely related to the human STE20-subfamily kinases STLK6 (SEQ ID No. 99) and SPAK (AFO99989), sharing 51% and 33% amino acid identity, respectively, over its full extent. It also shares significant homology to database entries from *Arabidopsis thaliana* (GB:AC002343) and *C.elegans* (GB:AL023843, GB:AL023843).

[0216] The 10 amino acid N-terminal domain of human STLK5 does not reveal any significant homologies to the protein database.

[0217] The 311 amino acid catalytic domain of human STLK5 shares 51% and 34% identity to STLK6 and SPAK, respectively. The catalytic domain of STLK5 contains a 45 amino acid insert between kinase subdomains X and XI relative to human STE20. Multiple human EST fragments as well as a murine EST (GB:AA575647) contain this insert providing evidence that this region is an integral part of STLK5.

[0218] The 52 amino acid C-terminal tail of human STLK5 shares 41.3% amino acid identity to human SOK-1 (GB:X99325). The weak sequence homology between the C-termini of human STLK5 and STE20, suggests it may also function as an inhibitory domain for its kinase.

Mammalian STLK6

[0219] The 2,001 bp human STLK6 nucleotide sequence of the complete cDNA encodes a polypeptide of 418 amino acids (SEQ ID NO:99) with a predicted molecular mass of 47,025 daltons. Analysis of the deduced amino acid sequence predicts STLK6 to be an intracellular STE20-subfamily kinase, lacking both a signal sequence and transmembrane domain. STLK6 contains a 57 amino acid N-terminal domain, a 312 amino acid catalytic domain with all the motifs characteristic of a serine/threonine kinase, followed by a 49 amino acid C-terminal domain.

[0220] STLK6 is most closely related to human STE20-subfamily kinases STLK5 (SEQ ID NO:97), STLK7 (SEQ ID NO:101), and SPAK (AFO99989), sharing 50%, 35%,

and 30% amino acid identity over its full extent. It also shares significant homology to database entries from *Arabidopsis thaliana* (GB:AC002343) and *C.elegans* (GB:U53153).

[0221] The 57 amino acid N-terminal domain of human STLK6 does not reveal any significant homologies in the protein database.

[0222] The 312 amino acid catalytic domain of human STLK6 shares 51 and 30 % identity to human STLK5 and SPAK, respectively.

[0223] The 49 amino acid C-terminal tail of human STLK6 shares low amino acid sequence identity (29%) with STLK5 and SPAK.

Mammalian STLK7

[0224] The 311 bp human STLK7 nucleotide sequence of the partial cDNA encodes a polypeptide of 103 amino acids (SEQ ID NO:101). Analysis of the deduced amino acid sequence predicts STLK7 to be an internal fragment of an intracellular STE20-family kinase. This sequence lacks the N- and C-terminal portions of STLK7 and contains only the N-terminal 103 amino acids of the predicted catalytic domain.

[0225] Human STLK7 is most closely related to human STE20-subfamily kinases SPAK (AFO99989), STLK5 (SEQ ID NO:97), and STLK6 (SEQ ID NO:99), sharing 86%, 38%, and 35% amino acid identity within this region of the kinase domain. It also shares significant homology to database entries from *Arabidopsis thaliana* (GB:AC002343) and *Drosophila melanogaster* (GB:AF006640).

Mammalian ZC1

[0226] The 3798 bp human ZC1 nucleotide sequence encodes a polypeptide of 1239 amino acids (SEQ ID NO:13) with a predicted molecular mass of 142,140 daltons. Analysis of the deduced amino acid sequence predicts ZC1 to be an intracellular serine/threonine kinase, lacking both a signal sequence and transmembrane domain. The full-length ZC1 protein contains a 22 amino acid N-terminus, a 267 amino acid catalytic domain with all the motifs characteristic of a serine/threonine kinase, a 237 amino acid region predicted to form a coiled-coil structure, a 114 amino acid proline-rich region, a 256 amino acid spacer region, followed by a 343 amino acid C-terminal domain containing a potential Rab/Rho-binding region.

[0227] ZC1 is most closely related to the human STE20-subfamily kinases ZC2 (SEQ ID NO:14), ZC3 (SEQ ID NO:15), and ZC4 (SEQ ID NO:16), sharing 61.7%, 60.9%, and 43.8% amino acid identity, respectively. ZC1 also shares 45.5% amino acid identity to a *C. elegans* kinase encoded by the cosmid ZC504.4 (GB:Z50029). ZC1 exhibits 90.0% amino acid homology to murine NIK (GB:U88984), suggesting it may be the human orthologue of this STK.

[0228] The 22 amino acid N-terminal domain of human ZC1 is 58.8% identical to the *C. elegans* kinase encoded by the cosmid ZC504.4 (GB:Z50029), and 100% identical to murine NIK (GB: U88984). Human ZC1 lacks a glycine residue at position 2, and is therefore unlikely to undergo myristylation. A Smith-Waterman search of the nonredundant protein database does not reveal any significant homologies that might suggest a potential function for this domain.

[0229] The 267 amino acid catalytic domain of human ZC1 is most related to human STE20-subfamily kinases, ZC3 (SEQ ID NO:15), ZC2 (SEQ ID NO:14), KHS2 (SEQ ID NO:18), SOK-1 (GB:X99325), GCK (GB:U07349), and GEK2 (SEQ ID NO:107), and to the *C. elegans* kinase encoded by the cosmid ZC504.4 (GB:Z50029) sharing 90.6%, 90.2%, 50.6%, 47.4%, 45.4%, 42.5% and 82.6% amino acid identity, respectively. The ZC1 kinase domain shares 98.1% identity to murine NIK (GB:U88984). ZC1 contains the potential “TPY” regulatory phosphorylation site in its activation loop. This “TPY” motif is conserved in other STE20-related kinases, including ZC2, ZC3, ZC4, GEK2, KHS2, SULU1, SULU3, PAK4 and PAK5.

[0230] Immediately C-terminal to the kinase domain of human ZC1 is a 237 amino acid region predicted to form a coiled-coil structure based on the Lupas algorithm (Lupas, A. Meth. Enzymol. 266, 513-525 (1996)). This region of ZC1 is most related to human STE20-subfamily kinases, ZC3 (SEQ ID NO:15), ZC2 (SEQ ID NO:14), and GEK2 (SEQ ID NO:107), as well as to human PITSLRE (GB:U04824) sharing 65.5%, 65.4%, 25.3%, and 29.0% amino acid identity, respectively. The ZC1 coiled-coil domain also shares 90.6% amino acid homology to murine NIK. The *C. elegans* homologue ZC504.4 shares 32.2% sequence identity over this region.

[0231] Within the predicted coiled-coil domain of human ZC1, and the related ZC3, is a region predicted to form a leucine zipper (Leu-X6-Leu-X6-Leu-X6-Leu-X20-

Leu-X6-Leu) (SEQ ID NO: 149). The fact that this leucine repeat exists within a predicted coiled-coil structure suggests that the leucine zipper may have a high probability of serving as a dimerization interface (Hirst, J.D. *et al* Protein Engineering 9 657-662 (1996)) mediating a potential inter- or intra-molecular dimerization of human ZC1.

[0232] The 114 amino acid proline-rich region of human ZC1 is most related to human STE20-subfamily kinases, ZC2 (SEQ ID NO:14) and ZC3 (SEQ ID NO:15), sharing 35.8%, and 24.9%, respectively. The ZC1 proline-rich domain shares 36.4% amino acid homology to murine NIK (GB:U88984). Three potential "PxxP" (SEQ ID NO: 148) SH3 domain-binding motifs (I, II and III) are found within the proline-rich region of human ZC1. Motif I is conserved in human ZC1 and *C. elegans* ZC504.4 (GB:Z50029). Motif II is conserved in ZC1, ZC2, ZC3, ZC4 and *C. elegans* ZC504.4. Motif III is conserved in ZC1, ZC2, ZC3 and ZC4. Motifs II and III of murine NIK have been shown to bind the SH3 motif of the adaptor molecule Nck (Su, Y-C. *et al*, EMBO J. 16, 1279-1290 (1997)). From this evidence, human ZC1 may have the potential to bind to Nck or other SH3 or WW domain-containing proteins and participate in growth factor-induced signaling pathways.

[0233] The 256 amino acid spacer region of human ZC1 is most related to human STE20-subfamily kinases, ZC2 (SEQ ID NO:14) and ZC3 (SEQ ID NO:15), as well as to human PITSLRE (GB:U04824), sharing 59.9%, 33.1%, 29.6%, and 26.4% amino acid identity, respectively. It also shares 59.9% amino acid homology to murine NIK. The *C. elegans* homologue ZC504.4 has only limited sequence similarity in this spacer region.

[0234] The 343 amino acid C-terminal of human ZC1 is most related to human STE20-subfamily kinases, ZC3 (SEQ ID NO:15), ZC2 (SEQ ID NO:14), and ZC4 (SEQ ID NO:16), sharing 89.2%, 88.9%, and 42.3%, amino acid identity, respectively. The ZC1 C-terminal domain also shares 98.8% amino acid identity to murine NIK. The *C. elegans* homologue ZC504.4 also shares 68.7% amino acid identity with the C-tail of human ZC1.

A lower, yet significant, homology is also evident to human KHS2 (SEQ ID NO:18), GCK (GB:U07349), and murine citron (GB:U07349) with 26.6%, 23.1% and 36.2% amino acid identity, respectively. GCK is a STE20-family kinase whose C-terminal domain has been shown to bind the small G-protein Rab8 (Ren, M. *et al.*, Proc. Natl. Acad. Sci. 93, 5151-5155 (1996)). Citron is a non-kinase Rho-binding protein (Madaule,

P. *et al.*, FEBS Lett. 377, 243-238 (1995)).

[0235] The sequence similarity of the C-terminal region of ZC1 to proteins that have potential Rab- or Rho-binding domains suggests that ZC1 may signal through a small G-protein-dependant pathway.

Mammalian ZC2

[0236] The 4055 bp human ZC2 nucleotide sequence of the partial cDNA encodes a polypeptide of 1297 amino acids (SEQ ID NO:14) with a predicted molecular mass of 147,785 daltons. Analysis of the deduced amino acid sequence predicts ZC2 to be an intracellular serine/threonine kinase, lacking both a signal sequence and transmembrane domain, however the cDNA clone lacks an initiating ATG, so the full extent of its N-terminus is not known. The N-terminally truncated ZC2 protein contains a 255 amino acid catalytic domain with all the motifs characteristic of a serine/threonine kinase, a 187 amino acid region predicted to form a coiled-coil structure, a 184 amino acid proline-rich region, a 328 amino acid spacer region, followed by a 343 amino acid C-terminal domain containing a potential Rab/Rho-binding region.

[0237] ZC2 is most closely related to the human STE20-subfamily kinases ZC3 (SEQ ID NO:15), ZC1 (SEQ ID NO:13), and ZC4 (SEQ ID NO:16), sharing 88.3%, 61.7%, and 41.9% amino acid identity, respectively, and shares 41.7% amino acid identity to a *C. elegans* kinase encoded by the cosmid ZC504.4 (GB:Z50029).

[0238] The 255 amino acid catalytic domain of human ZC2 is most related to human STE20-subfamily kinases, ZC1 (SEQ ID NO:13), ZC3 (SEQ ID NO:15), SOK-1 (GB:X99325), KHS2 (SEQ ID NO:18), MST1 (GB:U18297), and GCK (GB:U07349), and to the *C. elegans* kinase encoded by the cosmid ZC504.4 (GB:Z50029) sharing 90.2%, 89.8%, 49.0%, 48.6%, 47.9%, 45.0 and 76.7% amino acid identity, respectively. ZC2 contains the potential "TPY" regulatory phosphorylation site in its activation loop. This "TPY" motif is conserved in other STE20-related kinases, including ZC1, ZC3, ZC4, GEK2, KHS2, SULU1, SULU3, PAK4 and PAK5.

[0239] Immediately C-terminal to the kinase domain of human ZC2 is a 187 amino acid region predicted to form a coiled-coil structure based on the Lupas algorithm (*supra*). This region of ZC2 is most related to human STE20-subfamily kinases, ZC1 (SEQ ID

NO:13), ZC3 (SEQ ID NO:15), and GEK2 (SEQ ID NO:107), as well as to human PITSLRE (GB:U04824), sharing 65.8%, 61.5%, 29.7% and 29.6% amino acid identity, respectively. The *C. elegans* homologue ZC504.4 shares 30.8% sequence identity over this region. Human ZC2 lacks the potential leucine zipper found in ZC1 as a consequence of a 29 amino acid deletion relative to ZC1 and ZC3.

[0240] The 184 amino acid proline-rich region of human ZC2 is most related to human STE20-subfamily kinases, ZC3 (SEQ ID NO:15) and ZC1 (SEQ ID NO:13), sharing 35.9% and 28.6%, amino acid identity, respectively. Significant homology is also evident to the murine WW domain-binding protein WBP7 (GB:U92455), and to the human SH3 domain-binding protein 3BP-1 (GB:X87671), with 27.7% and 25.3% amino acid identity, respectively.

[0241] ZC2 contains two of the potential "PxxP" (SEQ ID NO: 148) SH3 domain-binding motifs (II and III) found within the proline-rich region of human ZC1. Motif II is conserved in ZC1, ZC3, ZC4 and *C. elegans* ZC504.4, and Motif III is conserved in ZC1, ZC3 and ZC4. Motifs II and III of murine NIK have been shown to bind the SH3 motif of the adaptor molecule Nck. From this evidence, human ZC1 may have the potential to bind to Nck or other SH3 or WW domain-containing proteins, and to participate in growth factor-induced signaling pathways.

[0242] The 328 amino acid spacer region of human ZC2 is most related to human STE20-subfamily kinases ZC1 (SEQ ID NO:13) and ZC3 (SEQ ID NO:15), and to murine NIK (GB:U88984), sharing 31.6%, 26.9% and 25.9% amino acid identity, respectively. The *C. elegans* homologue ZC504.4 has only limited sequence similarity in this spacer region.

[0243] The 343 amino acid C-terminal of human ZC2 is most related to human STE20-subfamily kinases ZC1 (SEQ ID NO:13), ZC3 (SEQ ID NO:15) and ZC4 (SEQ ID NO:16), and to murine NIK (GB:U88984), sharing 88.9%, 88.3%, 41.9%, and 88.0%, amino acid identity, respectively. The *C. elegans* homologue, ZC504.4, also shares 67.2% amino acid identity with the C-tail of human ZC2. A lower, yet significant, homology is also evident to human GCK (GB:U07349), murine citron (GB:U07349), and the *S. cerevisiae* ROM2 protein (GB:U19103), a Rho1 GDP/GTP exchange factor, with 22.3%, 22.2% and 21.9% amino acid identity, respectively.

[0244] The sequence similarity of the C-terminal region of ZC2 to proteins that have potential Rab- or Rho-binding domains suggests that ZC2, like ZC1, may also signal through a small G-protein-dependant pathway.

Mammalian ZC3

[0245] The 4133 bp human ZC3 nucleotide sequence of the partial cDNA encodes a polypeptide of 1326 amino acids (SEQ ID NO:15) with a predicted molecular mass of 149,906 daltons. Analysis of the deduced amino acid sequence predicts ZC3 to be an intracellular serine/threonine kinase, lacking both a signal sequence and transmembrane domain, however the cDNA clone lacks an initiating ATG, so the full extent of its N-terminus is not known. The N-terminally truncated ZC3 protein contains a 255 amino acid catalytic domain with all the motifs characteristic of a serine/threonine kinase: a 221 amino acid region predicted to form a coiled-coil structure, a 204 amino acid proline-rich region, and a 303 amino acid spacer region followed by a 343 amino acid C-terminal domain containing a potential Rab/Rho-binding region.

[0246] ZC3 is most closely related to the human STE20-subfamily kinases ZC1 (SEQ ID NO:13), ZC2 (SEQ ID NO:14), and ZC4 (SEQ ID NO:16), sharing 62.0%, 61.0%, and 42.5% amino acid identity, respectively and shares 46.7% amino acid identity to a *C. elegans* kinase encoded by the cosmid ZC504.4 (GB:Z50029).

[0247] The 255 amino acid catalytic domain of human ZC3 is most related to human STE20-subfamily kinases, ZC1 (SEQ ID NO:13), ZC2 (SEQ ID NO:14), SOK-1 (GB:X99325), KHS2 (SEQ ID NO:18), GCK (GB:U07349), SULU1 (SEQ ID NO:22), and GEK2 (SEQ ID NO:107), and to the *C. elegans* kinase encoded by the cosmid ZC504.4 (GB:Z50029) sharing 90.6%, 89.3%, 49.0%, 48.3%, 45.0%, 43.1%, 42.3% and 76.7% amino acid identity, respectively. ZC1 contains the potential “TPY” regulatory phosphorylation site in its activation loop. This “TPY” motif is conserved in other STE20-related kinases, including ZC1, ZC2, GEK2, KHS2, SULU1, SULU3, PAK4 and PAK5.

[0248] Immediately C-terminal to the kinase domain of human ZC3 is a 221 amino acid region predicted to form a coiled-coil structure based on the Lupas algorithm (supra). This region of ZC3 is most homologous to human STE20-subfamily kinases, ZC1 (SEQ

ID NO:13), ZC2 (SEQ ID NO:14), and GEK2 (SEQ ID NO:107), sharing 66.9%, 61.5%, and 27.5% identity, as well as to rat PLC-beta (GB:A45493) and human PITSLRE (GB:H54024) sharing 29.6% and 25.9% amino acid identity, respectively. The *C. elegans* homologue ZC504.4 shares 26.8% sequence identity over this region.

[0249] Within the predicted coiled-coil domain of human ZC3, and the related ZC1, is a region predicted to form a leucine zipper (Leu-X6-Leu-X6-Leu-X6-Leu-X20-Leu-X6-Leu) (SEQ ID NO: 149). The fact that this leucine repeat exists within a predicted coiled-coil structure suggests that the leucine zipper may have a high probability of serving as a dimerization interface (Hirst, J.D. *et al* Protein Engineering 9 657-662 (1996)) mediating a potential inter- or intra-molecular dimerization of human ZC3.

[0250] The 204 amino acid proline-rich region of human ZC3 is most related to human STE20-subfamily kinases, ZC1 (SEQ ID NO:13) and ZC2 (SEQ ID NO:14), sharing 66.9% and 61.5% amino acid identity, respectively.

[0251] ZC3 contains two of the potential "PxxP" (SEQ ID NO: 148) SH3 domain-binding motifs (II and III) found within the proline-rich region of human ZC1. Motif II is conserved in ZC1, ZC2, ZC4 and *C. elegans* ZC504.4; Motif III is conserved in ZC1, ZC2 and ZC4. Motifs II and III of murine NIK have been shown to bind the SH3 motif of the adaptor molecule Nck. From this evidence, human ZC3 may have the potential to bind to Nck or other SH3 or WW domain-containing proteins and participate in growth factor-induced signaling pathways.

[0252] The 303 amino acid acid spacer region of human ZC3 is most related to human STE20-subfamily kinases, ZC1 (SEQ ID NO:13) and ZC2 (SEQ ID NO:14) sharing 30.1%, and 27.1% amino acid identity, respectively. The *C. elegans* homologue ZC504.4 lacks nearly the entire spacer region of ZC3.

[0253] The 343 amino acid C-terminal of human ZC3 is most related to human STE20-subfamily kinases, ZC1 (SEQ ID NO:13), ZC2 (SEQ ID NO:14) and ZC4 (SEQ ID NO:16), sharing 89.2%, 88.9%, and 42.5%, amino acid identity, respectively. The *C. elegans* homologue ZC504.4 also shares 67.2% amino acid identity with the C-tail of human ZC3. A lower, yet significant, homology is also evident to human GCK (GB:U07349), as well as to the non-kinases murine citron (GB:U07349) and the *S. cerevisiae* ROM2 protein (GB:U19103), a Rho1 GDP/GTP exchange factor, with 21.6%,

32.4% and 22.9% amino acid identity, respectively.

[0254] The sequence similarity of the C-terminal region of ZC3 to proteins that have potential Rab- or Rho-binding domains suggests that ZC3, like ZC1 and ZC2, may signal through a small G-protein-dependant pathway.

Mammalian ZC4

[0255] The 3,684 bp human ZC4 nucleotide sequence of the complete cDNA encodes a polypeptide of 1,227 amino acids (SEQ ID NO:105) with a predicted molecular mass of 138,205 Daltons. Analysis of the deduced amino acid sequence predicts ZC4 to be an intracellular STE20-subfamily kinase, lacking both a signal sequence and a transmembrane domain. The full-length ZC4 protein contains a 25 amino acid N-terminus, a 265 amino acid catalytic domain with all the motifs characteristic of a serine/threonine kinase, a 108 amino acid region predicted to form a coiled-coil structure, a 231 amino acid proline-rich region, a 40 amino acid region predicted to form a coiled-coil structure spacer region, a 204 amino acid spacer region (domain B), followed by a 355 amino acid C-terminal domain containing a potential Rab/Rho-binding region (domain C).

[0256] ZC4 is most closely related to human ZC1 (SEQ ID NO:13, also known as human HGK, human KIAA0687, murine NIK, human AC005035, human NIK, and *C. elegans* MIG-15), ZC2 (SEQ ID NO:14, similar to partial sequence human KIAA0551), and ZC3 (SEQ ID NO:15). An assembled genomic fragment in the database (Z83850) is identical to ZC4, except for inappropriate identification of the exon boundaries. (Abo *et al.* (1998) EMBO J. 17: 6527-6540.)

[0257] The 25 amino acid N-terminal domain of human ZC4 shares weak homology to human ZC1 in its C-terminal extent, but otherwise does not reveal any significant homologies to the protein database.

[0258] The 265 amino acid catalytic domain of human ZC4 is most related to human ZC1 (SEQ ID NO:13), ZC3 (SEQ ID NO:15), and ZC2 (SEQ ID NO:14), sharing 63%, 64% and 62% amino acid identity, respectively.

[0259] Immediately C-terminal to the kinase domain of human ZC4 is a 108 amino acid region predicted to form a coiled-coil structure based on the Lupas algorithm (*supra*). This region is most related to human ZC1 (SEQ ID NO:13), ZC3 (SEQ ID NO:15), and

ZC2 (SEQ ID NO:14), sharing 29%, 25% and 20% amino acid identity, respectively.

[0260] The 231 amino acid proline-rich region of human ZC4 does not reveal any significant homologies to the protein database. This region of ZC4 contains two "PxxP" (SEQ ID NO: 148) motifs that could potentially bind to proteins containing SH3 or WW domains and allow ZC4 to participate in growth factor activated signaling pathways. In addition, within the pro-rich domain of human ZC4 is a region predicted to form a leucine zipper (Leu-X6-Leu-X6-Leu-X6-Leu-X20-Leu-X6-Leu) (SEQ ID NO: 149) which may serve as a dimerization interface. The ZC STE20 subfamily kinases (ZC1, ZC2 and ZC3) have similarly located "PxxP" (SEQ ID NO: 148) motifs and potential Leu zippers.

[0261] Immediately C-terminal to the proline-rich region of human ZC4 is a 40 amino acid region also predicted to form a coiled-coil structure based on the Lupas algorithm. This region of human ZC4 does not reveal any significant homologies to the protein database.

[0262] The 204 amino acid acidic- and serine-rich domain "B" of ZC4 does not reveal any significant homologies to the protein database.

[0263] The 355 amino acid C-terminal of human ZC4 is most related to human ZC1 (SEQ ID NO:13), ZC3 (SEQ ID NO:15), and ZC2 (SEQ ID NO:14), sharing 43%, 42% and 42% amino acid identity, respectively.

[0264] The sequence similarity of the C-terminal region of ZC4 to proteins that have potential Rab- or Rho-binding domains suggests that ZC4, like other ZC-subfamily STE20 kinases, may signal through a small G-protein-dependant pathway.

Mammalian KHS2

[0265] The 4023 bp human KHS2 nucleotide sequence encodes a polypeptide of 894 amino acids (SEQ ID NO:18) with a predicted molecular mass of 101,327 daltons. Analysis of the deduced amino acid sequence predicts KHS2 to be an intracellular serine/threonine kinase, lacking both a signal sequence and transmembrane domain. The full-length KHS2 protein contains a 13 amino acid N-terminus, a 260 amino acid catalytic domain with all the motifs characteristic of a serine/threonine kinase, a 73 amino acid spacer region, a 188 proline-rich region, followed by a 360 amino acid C-terminal domain containing a potential Rab/Rho-binding site.

[0266] KHS2 is most closely related to the human STE20-subfamily kinases KHS1 (GB:U177129), GCK (GB:U07349), and HPK1 (GB:U07349), sharing 65.5%, 51.9%, and 44.9% amino acid identity, respectively and shares 38.5% amino acid identity to a *C. elegans* STK (GB:U55363).

[0267] The 13 amino acid N-terminal domain of human KHS2 does not reveal any significant homologies that might suggest a potential function for this domain when examined by a Smith-Waterman alignment to the nonredundant protein database. Human KHS2 lacks a glycine residue at position 2, and is therefore unlikely to undergo myristylation.

[0268] The 260 amino acid catalytic domain of human KHS2 is most related to human STE20-subfamily kinases KHS1 (GB:U177129), GCK (GB:U07349), HPK1 (GB:U66464), SOK-1 (GB:X99325), MST1 (GB:U18297), ZC1 (SEQ ID NO:13), and to the *C. elegans* kinase (GB:U55363), sharing 85.4%, 75.1%, 67.7%, 51.4%, 48.1%, 49.8% and 72.0% amino acid identity, respectively. KHS2 contains the potential “TPY” regulatory phosphorylation site in its activation loop. This “TPY” motif is conserved in other STE20-related kinases, including ZC1, ZC2, ZC3, ZC4, GEK2, SULU1, SULU3, PAK4 and PAK5.

[0269] The 73 amino acid spacer region of human KHS2 is most related to human STE20-subfamily kinases, KHS1 (GB:U177129), HPK1 (GB:U66464) and GCK (GB:U07349), sharing 60.3%, 43.5% and 44.0%, amino acid identity, respectively.

[0270] The 188 amino acid proline-rich region of human KHS2 is most related to human STE20-subfamily kinases, HPK1 (GB:U66464), GCK (GB:U07349) and KHS1 (GB:U177129), sharing 33.3%, 31.9% and 31.4%, amino acid identity, respectively.

[0271] Two potential “PxxP” (SEQ ID NO: 148) SH3 domain-binding motifs (I and II) are found within the proline-rich region of human KHS2. Motif I is conserved with human KHS1 and HPK1; motif II is conserved with GCK and KHS2. A 192 amino acid region of human HPK1 containing motif II has been shown to bind to the C-terminal SH3 motif of the adaptor molecule Grb2 (Anafi, M *et al*, J. Biol. Chem. J. 272, 27804-27811 (1997)). Human KHS2 may bind SH3 or WW domain-containing proteins through this proline-rich region.

[0272] The 360 amino acid C-terminal of human KHS2 is most related to KHS1

(GB:U177129), GCK (GB:U07349) and HPK1 (GB:U66464), and to the *C. elegans* kinase (GB:U55363), sharing 74.9%, 54.8%, 42.9%, and 31.0%, amino acid identity, respectively. GCK is a STE20-family kinase whose C-terminal domain has been shown to bind the small G-protein Rab8 (Ren, M. *et al.*, Proc. Natl. Acad. Sci. 93, 5151-5155 (1996)).

Mammalian SULU1

[0273] The 4196 bp human SULU1 nucleotide sequence encodes a polypeptide of 898 amino acids (SEQ ID NO:22) with a predicted molecular mass of 105,402 daltons. Analysis of the deduced amino acid sequence predicts SULU1 to be an intracellular serine/threonine kinase, lacking both a signal sequence and transmembrane domain. The full-length SULU1 protein contains a 21 amino acid N-terminus, a 256 amino acid catalytic domain with all the motifs characteristic of a serine/threonine kinase, a 150 amino acid spacer region, a 210 amino acid region predicted to form a coiled-coil structure, a 114 amino acid spacer region and a 147 amino acid C-terminal domain predicted to form a coiled-coil structure.

[0274] SULU1 is most closely related to the STE20-subfamily kinases murine SULU3 (SEQ ID NO:24), human SULU3 (SEQ ID NO:23), and to the *C. elegans* kinase SULU (GB:U11280), sharing 68.9%, 72.2% and 38.2% amino acid identity, respectively.

[0275] The 21 amino acid N-terminal domain of human SULU1 is most related to murine SULU3 (SEQ ID NO:24) and to the *C. elegans* kinase SULU (GB:U11280), sharing 86.3% and 62.3% amino acid identity. Human SULU1 lacks a glycine residue at position 2, and is therefore unlikely to undergo myristoylation. A Smith-Waterman search of the nonredundant protein database does not reveal any significant homologies that might suggest a potential function for this domain.

[0276] The 256 amino acid catalytic domain of human SULU1 is most related to murine SULU3 (SEQ ID NO:24), and to human SOK-1 (GB:X99325), STK2 (SEQ ID NO:5), MST1 (GB:U18297), PAK1 (GB:U24152), ZC2 (SEQ ID NO:14), and KHS2 (SEQ ID NO:18) sharing 86.3%, 48.1%, 46.9%, 45.2%, 43.3%, 43.1% and 42.0% amino acid identity, respectively. The *C. elegans* SULU STK (GB:U11280) shares 62.3% sequence identity over this region. SULU1 contains the potential "TPY" regulatory

phosphorylation site in its activation loop. This “TPY” motif is conserved in other STE20-related kinases, including ZC1, ZC2, ZC3, ZC4, GEK2, KHS2, SULU3, PAK4 and PAK5.

[0277] The 150 amino acid spacer region of human SULU1 is most related to human SULU3 (SEQ ID NO:23) and to the *C. elegans* kinase (GB:U11280), sharing 53.5% and 10.4% amino acid identity, respectively.

[0278] Immediately C-terminal to the spacer region of human SULU1 is a 210 amino acid region predicted to form a coiled-coil structure based on the Lupas algorithm. This region of SULU1 is most related to SULU3 (SEQ ID NO:23), the *C. elegans* SULU kinase (GB:U11280), GEK 2 (SEQ ID NO:107) and ZC1 (SEQ ID NO:13), sharing 68.6%, 26.8%, 23.2%, and 22.8% amino acid identity, respectively.

[0279] The 114 amino acid spacer region human SULU1 is most related to human SULU3 (SEQ ID NO:24) with 73.7% amino acid sequence identity. A lower, yet significant, homology is also evident to murine PITSLRE (GB:U04824) and DLK (GB:A55318), human ZC1 (SEQ ID NO:13) and GEK 2 (SEQ ID NO:107), as well as to the *C. elegans* SULU STK (GB:U11280), sharing 39.7%, 35.4%, 29.5%, 23.6% and 37.6% amino acid identity, respectively.

[0280] Immediately C-terminal to the second spacer region of human SULU1 is a 147 amino acid region predicted to form a coiled-coil structure based on the Lupas algorithm. This region of SULU1 is most related to human SULU3 (SEQ ID NO:24), ZC1 (SEQ ID NO:13) and GEK 2 (SEQ ID NO:107), as well as to the *C. elegans* SULU STK (GB:U11280), sharing 73.3%, 28.4%, 26.1% and 39.5%, amino acid identity, respectively.

Mammalian (human) SULU3

[0281] The 3824 bp partial cDNA human SULU3 nucleotide sequence encodes a polypeptide of 786 amino acids (SEQ ID NO:23) with a predicted molecular mass of 92,037 daltons. Analysis of the deduced amino acid sequence predicts SULU3 to be an intracellular serine/threonine kinase lacking a transmembrane domain. The N-terminally truncated human SULU3 protein contains a 66 amino acid partial catalytic domain followed by a 149 amino acid spacer region, a 210 amino acid region predicted to form a coiled-coil structure, a second spacer region of 114 amino acids, a 247 amino acid C-

terminal region predicted to form a second coiled-coil structure and a 100 amino acid C-terminal tail.

[0282] Human SULU3 is most closely related murine SULU3 (SEQ ID NO:24), human SULU1 (SEQ ID NO:22), and to the *C. elegans* SULU kinase (GB:U11280), sharing 66.3%, 68.9% and 32.9% amino acid identity, respectively. The high sequence homology between murine and human SULU3 suggests that these two proteins are orthologs of each other.

[0283] The 66 amino acid partial catalytic domain of human SULU3 is most related to murine SULU3 (SEQ ID NO:24), and to the human STE20 subfamily kinases ZC1 (SEQ ID NO:13), STE20 (GB:X99325), KHS1(GB:U177129) and GEK 2 (SEQ ID NO:107), as well as to the *C. elegans* SULU kinase (GB:U11280), sharing 83.3%, 47.0%, 45.5%, 43.5%,41.8% and 55.6% amino acid identity, respectively.

[0284] The 149 amino acid spacer region of human SULU3 is most related to murine SULU3 (SEQ ID NO:24), human STE20 (GB:X99325), MST1 (GB:U18297), and to the *C.elegans* SULU kinase (GB:U11280) sharing 98.7%, 21.9% and 21.8% amino acid identity, respectively.

[0285] Immediately C-terminal to the first spacer region of human SULU3 is a 210 amino acid region predicted to form a coiled-coil structure based on the Lupas algorithm. This region of SULU3 is most related to murine SULU3 (SEQ ID NO:24), and to human SULU1 (SEQ ID NO:22), ZC1 (SEQ ID NO:13) and GEK 2 (SEQ ID NO:107), as well as to the *C. elegans* SULU kinase (GB:U11280), sharing 99. 5%, 68.6%, 27.4% and 22.5% amino acid identity, respectively.

[0286] The 114 amino acid second spacer region of human SULU3 is most related to murine SULU3 (SEQ ID NO:24), and to human SULU1 (SEQ ID NO:22) GEK 2 (SEQ ID NO:107), and ZC1 (SEQ ID NO:13), as well as to the *C. elegans* SULU kinase (GB:U11280), sharing 99.1%, 73.7%, 24.6%,24.1% and 41.2% amino acid identity, respectively.

[0287] Immediately C-terminal to the second spacer region of human SULU3 is a 247 amino acid region predicted to form a coiled-coil structure based on the Lupas algorithm (supra). This region of SULU3 is most related to human SULU1 (SEQ ID NO:22) and ZC1 (SEQ ID NO:13) as well as to rat PKN-(GB:D26180) murine pl60

ROCK1 (GB:U58512), and the *C. elegans* SULU kinase (GB:U11280), sharing 73.7%, 26.7%, 24.0% and 21.0% amino acid identity, respectively.

[0288] The 100 amino acid C-tail of human SULU3 is most related to a human prion protein (GB:L38993), with 45.0% amino acid identity.

Mammalian (murine) SULU3

[0289] The 2249 bp murine, partial cDNA SULU3 nucleotide sequence encodes a polypeptide of 748 amino acids (SEQ ID NO:24) with a predicted molecular mass of 87,520 daltons. Analysis of the deduced amino acid sequence predicts SULU3 to be an intracellular serine/threonine kinase, lacking both a signal sequence and transmembrane domain. The partial murine SULU3 protein contains a 25 amino acid N-terminus, a 248 amino acid catalytic domain with all the motifs characteristic of a serine/threonine kinase, a 149 amino acid spacer region, a 210 amino acid region predicted to form a coiled-coil structure, and a 116 amino acid spacer region.

[0290] Murine SULU3 is most closely related to human SULU3 (SEQ ID NO:23) and SULU1 (SEQ ID NO:22), as well as to the *C. elegans* SULU kinase (GB:U11280), sharing 97.0%, 72.3% and 38.4% amino acid identity, respectively. The high sequence homology between murine and human SULU3 suggests that these two proteins are orthologs.

[0291] The 25 amino acid N-terminal domain of murine SULU3 is most related to human SULU1 (SEQ ID NO:22) and to the *C. elegans* SULU kinase (GB:U11280), sharing 70.0% and 44.4% amino acid identity, respectively.

[0292] Murine SULU3 lacks a glycine residue at position 2, and is therefore unlikely to undergo myristoylation. A Smith-Waterman search of the nonredundant protein database does not reveal any significant homologies that might suggest a potential function for this domain.

[0293] The 248 amino acid catalytic domain of murine SULU3 is most related to human SULU1 (SEQ ID NO:22), STE20 (GB:X99325), ZC1 (SEQ ID NO:13), and KHS1 (GB:U77129), as well as to the *C. elegans* SULU kinase (GB:U11280), sharing 86.7%, 46.6%, 43.3%, 59.4% amino acid identity, respectively. Murine SULU3 contains the potential "TPY" regulatory phosphorylation site in its activation loop. This "TPY" motif is

conserved in other STE2O-related kinases, including ZC2, ZC3, ZC4, GEK2, KHS2, SULU1, SULU3, PAK4 and PAK5.

[0294] The 149 amino acid spacer of murine SULU3 is most related to human SULU3 (SEQ ID NO:23), SULU1 (SEQ ID NO:22), and STE20 (GB:X99325), as well as to the *C. elegans* SULU (GB:U11280) and the *S. cerevisiae* STE20 (GB:L04655) kinases, sharing 98.7%, 53.4%, 21.9%, 59.4% and 21.9% amino acid identity, respectively.

[0295] Immediately C-terminal to the spacer region of murine SULU3 is a 210 amino acid region predicted to form a coiled-coil structure based on the Lupas algorithm. This region of murine SULU3 is most related to human SULU3 (SEQ ID NO:23), ZC1 (SEQ ID NO:13), and GEK 2 (SEQ ID NO:107), as well as to the *C. elegans* SULU kinase (GB:U11280), sharing 99.5%, 27.4%, 22.5% and 29.2% amino acid identity, respectively.

[0296] The 116 amino acid C-terminal spacer region of murine SULU3 is most related to human SULU3 (SEQ ID NO:23), GEK 2 (SEQ ID NO:107), and ZC1 (SEQ ID NO:13), well as to the *C. elegans* SULU kinase (GB:U11280), sharing 98.3%, 24.6%, 24.1% and 40.5% amino acid identity, respectively.

Mammalian (murine/human) SULU3

[0297] The 2249 bp murine SULU3 and the 3824 bp human SULU3 cDNAs contain a 1620 nucleotide overlap (541 amino acids) with 90% and 98% DNA and amino acid sequence identity, respectively. Owing to the high degree of sequence identity in this extended overlap, we propose that these are functional orthologues of a single gene. The combined murine/human 4492 bp SULU3 sequence encodes a polypeptide of 1001 amino acids (SEQ ID NO:31) with a predicted molecular mass of 116,069 daltons. Analysis of the deduced amino acid sequence predicts SULU3 to be an intracellular serine/threonine kinase, lacking both a signal sequence and transmembrane domain. SULU3 contains a 25 amino acid N-terminus, a 248 amino acid catalytic domain with all the motifs characteristic of a serine/threonine kinase, a 149 amino acid spacer region, a 210 amino acid region predicted to form a coiled-coil structure and a second spacer region of 114 amino acids, a 247 amino acid C-terminal region predicted to form a second coiled-coil structure and a 100 amino acid C-terminal tail. The murine SULU3 clone lacks the region from the second C-terminal coiled-coil to the C-terminus, whereas the human clone lacks

the N-terminal domain, and all but 66 amino acids of the 248 amino acid kinase domain.

[0298] SULU3 is most closely related to SULU1 (SEQ ID NO:22) and the *C. elegans* SULU kinase (GB:U11280) sharing 72.3% and 38.4% amino acid identity, respectively.

[0299] The 25 amino acid N-terminal domain of SULU3 is most related to human SULU1 (SEQ ID NO:22) and to the *C. elegans* SULU kinase (GB:U11280), sharing 70.0% and 44.4% amino acid identity, respectively. SULU3 lacks a glycine residue at position 2, and is therefore unlikely to undergo myristylation. A Smith-Waterman search of the nonredundant protein database does not reveal any significant homologies that might suggest a potential function for this domain.

[0300] The 248 amino acid catalytic domain of SULU3 is most related to human SULU1 (SEQ ID NO:22), SOK-1 (GB:X99325), ZC1 (SEQ ID NO:13), KHS1 (GB:U77129) and the *C. elegans* SULU kinase (GB:U11280), sharing 86.7%, 46.6%, 43.3%, 42.0% and 59.4% amino acid identity, respectively. SULU3 contains the potential “TPY” regulatory phosphorylation site in its activation loop. This “TPY” motif is conserved in other STE20-related kinases, including ZC2, ZC3, ZC4, GEK2, KHS2, SULU1, PAK4 and PAK5.

[0301] The 149 amino acid spacer of SULU3 is most related to SULU1 (SEQ ID NO:22) and SOK-1 (GB:X99325), and to the *C. elegans* SULU (GB:U11280), and *S. cerevisiae* STE20 (GB:L04655) kinases, sharing 53.4%, 21.9%, 59.4% and 21.9% amino acid identity, respectively.

[0302] Immediately C-terminal to the spacer region of SULU3 is a 210 amino acid region predicted to form a coiled-coil structure based on the Lupas algorithm. This region is most related to ZC1 (SEQ ID NO:13), GEK 2 (SEQ ID NO:107), and the *C. elegans* SULU kinase (GB:U11280), sharing 27.4% 22.5% and 29.2% amino acid identity, respectively.

[0303] The 114 amino acid spacer region of SULU3 is most related to human SULU1 (SEQ ID NO:22), GEK 2 (SEQ ID NO:107), ZC1 (SEQ ID NO:13), and to the *C. elegans* SULU kinase (GB:U11280), sharing 73.7%, 24.6%, 24.1% and 41.2% amino acid identity, respectively.

[0304] Immediately C-terminal to the second spacer region of SULU3 is a 247

amino acid region predicted to form a coiled-coil structure based on the Lupas algorithm. This region of SULU3 is most related to human SULU1 (SEQ ID NO:22) and ZC1 (SEQ ID NO:13), as well as to rat PKN (GB:D26180), murine p160 ROCK1 (GB:U58512) and the *C. elegans* SULU kinase (GB:U11280), sharing 73.7%, 26.7%, 24.0%, 21.0% and 37.6% amino acid identity, respectively.

[0305] The 100 amino acid C-tail of SULU3 is most related to a human prion protein (GB:L38993) with 45.0% amino acid identity.

Mammalian GEK2

[0306] The 2926 bp human GEK2 nucleotide sequence of the complete cDNA encodes a polypeptide of 968 amino acids (SEQ ID NO:107) with a predicted molecular mass of 112,120 daltons. Analysis of the deduced amino acid sequence predicts GEK2 to be an intracellular serine/threonine kinase, lacking both a signal sequence and transmembrane domain. The complete GEK2 protein contains a 33 amino acid N-terminus, a 261 amino acid catalytic domain with all the motifs characteristic of a serine/threonine kinase, a 43 amino acid spacer region, a 135 amino acid proline-rich region, a 252 amino acid region predicted to form a coiled-coil structure followed by a 244 amino acid region also predicted to form a coiled-coil structure.

[0307] GEK2 is most closely related to rat AT1-46 (GB:U33472) (a partial cDNA that extends from the middle of the first potential coiled-coil domain of GEK2 to the C-terminus), murine LOK (GB:D89728), *Xenopus laevis* polo-like kinase 1 (GB:AF100165), and human SLK (GB:AB002804), sharing 91.3%, 88.5%, 65.0%, and 44.7% amino acid identity, respectively. The high sequence homology between human GEK2, murine LOK and rat AT1-46 suggests that human GEK2 is a highly related protein to the rodent forms, or alternatively, its orthologue. Recently, a full-length version of GEK2 was reported (STK10 or human LOK AB015718). The 968 amino acid sequence is 99% identical to GEK2 (SEQ ID NO:107).

[0308] The 33 amino acid N-terminal domain of human GEK2 is most related to murine LOK (GB:D89728) and to human SLK (GB:AB002804), sharing 100% and 54.5% amino acid identity, respectively.

[0309] Human GEK2 lacks a glycine residue at position 2, and is therefore unlikely

to undergo myristylation. A Smith-Waterman search of the nonredundant protein database does not reveal any significant homologies that might suggest a potential function for this domain.

[0310] The 261 amino acid catalytic domain of human GEK2 is most related to murine LOK (GB:D89728), rat AT1-46 (GB:D89728) and human SLK (GB:AB002804) as well as to a *C. elegans* kinase (GB:Z81460), sharing 97.7%, 90.8%, 54.5% and 55.9% amino acid identity, respectively. GEK2 contains the potential “TPY” regulatory phosphorylation site in its activation loop. This “TPY” motif is conserved in other STE20-related kinases, including ZC2, ZC3, ZC4, GEK2, KHS2, SULU1, SULU3, PAK4 and PAK5.

[0311] The 43 amino acid spacer region of human GEK2 is most related to murine LOK (GB:D89728) and to human SLK, sharing 83.7% and 77.6% amino acid identity, respectively.

[0312] The 135 amino acid proline-rich region of human GEK2 is most related to murine LOK (GB:D89728) with 66.2% amino acid identity, respectively. Within the proline-rich region of human GEK2 is a potential “PxxP” (SEQ ID NO: 148) SH3-binding domain conserved with murine LOK.

[0313] Immediately C-terminal to the proline-rich region of human GEK2 is a 252 amino acid region predicted to form a coiled-coil structure based on the Lupas algorithm. This region of human GEK2 is most related to rat AT1-46 (GB:D89728), murine LOK (GB:D89728) and human SLK (GB:AB002804), and ZC2 (SEQ ID NO:14), sharing 90.8%, 86.9%, 42.2%, and 29.7% amino acid identity, respectively.

[0314] Immediately C-terminal to the predicted coiled-coil structure of human GEK2 is a second potential coiled-coil structure of 244 amino acids predicted based on the Lupas algorithm. This region of human GEK2 is most related to rat AT1-46 (GB:D89728) and murine LOK (GB:D89728) as well as to human SLK (GB:AB002804) and ZC1 (SEQ ID NO:13), sharing 91.8%, 92.6%, 70.4% and 26.7% amino acid identity, respectively. The *C. elegans* kinase (GB:Z81460) shares 31.5% amino acid sequence identity over this region.

Mammalian PAK4

[0315] The 3604 bp human PAK4 nucleotide sequence encodes a polypeptide of 681 amino acids (SEQ ID NO:29) with a predicted molecular mass of 74,875 daltons. Analysis of the deduced amino acid sequence predicts PAK4 to be an intracellular serine/threonine kinase, lacking both a signal sequence and transmembrane domain. The full-length PAK4 protein contains a 51 amino acid N-terminus predicted to contain a rac-binding motif, a 173 amino acid insert relative to the known mammalian PAK proteins, a 169 amino acid spacer region, a 265 amino acid catalytic domain with all the motifs characteristic of a serine/threonine kinase and a 23 amino acid C-terminal tail.

[0316] PAK4 is most closely related to human PAK5 (SEQ ID NO:30), PAK1 (GB: U24152), and PAK65 (GB:U25975), as well as to a *C. elegans* kinase (GB: Z74029), sharing 76.8%, 49.5%, 49.8%, and 34.6% amino acid identity, respectively.

[0317] The 51 amino acid N-terminal domain of human PAK4 is most related to human PAK1 (GB:U24152), and PAK65 (GB:U25975), as well as to a *C.elegans* kinase (GB: Z74029), sharing 50.0%, 50.0% and 49.0% amino acid identity, respectively.

[0318] The 10 amino acid region at positions 13-23 of human PAK4 fits the consensus for a Cdc42/Rac-binding motif (SXPX4-6HXXH) (SEQ ID NO: 150) (Burbelo, P.D., Dreschel, D. and Hall, A. J. Bio. Chem. 270, 29071-29074 (1995)).

[0319] The 173 amino acid insert of human PAK4, relative to the known mammalian PAK proteins, is most related to a *C. elegans* kinase (GB: Z74029) with 39.0% amino acid identity. A Smith-Waterman search of the nonredundant protein database does not reveal any significant homologies that might suggest a potential function for this region.

[0320] The 169 amino acid spacer of human PAK4 does not reveal any significant homologies that might suggest a potential function for this region.

[0321] The equivalent spacer region in PAK1 binds to the guanine nucleotide exchange factor PIX (Manser, E. *et al* (1998) Molecular Cell, 1, 183-192). Since PAK4 differs substantially from PAK1 over this region, the spacer domain of PAK4 may differ in its guanine nucleotide exchange factor binding specificity, relative to PAK1.

[0322] The 265 amino acid catalytic domain of human PAK4 is most related to human PAK5 (SEQ ID NO:30), PAK1 (GB:U24152), GCK (GB:U07349), SOK-1 (GB:X99325), and SLK (GB:AB002804), as well as to the *C. elegans* (GB: Z74029), and

S. cerevisiae STE20-related kinases (GB:L04655), sharing 95.9%, 51.7%, 41.3%, 39.8%, 37.4%, 60.2% and 47.9% amino acid identity, respectively. PAK4 contains the potential "TPY" regulatory phosphorylation site in its activation loop. This "TPY" motif is conserved in other STE20-related kinases, including ZC1, ZC2, ZC3, ZC4, GEK2, KHS2, SULU1, SULU3 and PAK5.

[0323] The 23 amino acid C-tail of human PAK4 contains a sequence that is homologous to a G-protein beta subunit binding site (Leeuw, T. *et al.* Nature, 391, 191-195 (1998)). PAK4 has, therefore, the potential to be activated by both Cdc42- as well as G-protein-dependant pathways.

Mammalian PAK5

[0324] The 2,806 bp human PAK5 nucleotide sequence of the complete cDNA encodes a polypeptide of 591 amino acids (SEQ ID NO:103) with a predicted molecular mass of 64,071 Daltons. Analysis of the deduced amino acid sequence predicts PAK5 to be an intracellular STE20-subfamily kinase, lacking both a signal sequence and transmembrane domain. The full-length PAK5 protein contains a 52 amino acid N-terminus predicted to contain a p21 (small G-protein) binding domain (PDB or CRIB), a 121 amino acid insert relative to the known mammalian PAK proteins, a 134 amino spacer region, a 265 amino acid catalytic domain with all the motifs characteristic of a serine/threonine kinase and a 19 amino acid C-terminal tail.

[0325] PAK5 is most closely related to Human PAK4 (SEQ ID NO:29), *Drosophila melanogaster* PAK (also known as "mushroom bodies tiny") (AJ011578), C45B11.1b from *C. elegans* (Z74029), and human PAK3 (Q13177) sharing 48% (327/674 aa), 50% (330/651 aa), 43% (234/435 aa excluding gap), and 47% (190/405 aa excluding gap) amino acid identity, respectively. Recently, a full length version of PAK5 was reported (PAK4 AF005046) whose 591 amino acid sequence is identical to PAK5 (SEQ ID NO:103). (Abo, *et al.* (1998) EMBO J. 17:6527-6540).

[0326] The 52 amino acid N-terminal domain of human PAK5 is most related to human PAK4 (SEQ ID NO:29), *Drosophila melanogaster* PAK (AJ011578), C45B11.1b from *C. elegans* (Z74029), and human PAK3 (Q13177), sharing 65%, 57%, 54%, and 53% amino acid identity, respectively.

[0327] The 10 amino acid region at positions 12-22 of human PAK5 (FIG. 18) fits the consensus for a small G-protein binding domain (PDB or CRIB) (SXPX4-6HXXH) (SEQ ID NO: 150) (Burbelo, P.D., Dreschel, D. and Hall, A. J. Bio. Chem. 270, 29071-29074 (1995), hereby incorporated by reference herein in its entirety including any figures, tables, or drawings.).

[0328] The 121 amino acid insert of human PAK5 shares 43% amino acid identity with a similar domain from PAK4 (SEQ ID NO:29), but that is absent from other known PAKs.

[0329] The equivalent spacer region in PAK1 binds to the guanine nucleotide exchange factor PIX (Manser, E. et al (1998) Molecular Cell, 1, 183-192 hereby incorporated by reference herein in its entirety including any drawings, figures, or tables.). Since PAK5 differs substantially from PAK1 over this region, the spacer domain of PAK5 may differ in its guanine nucleotide exchange factor binding specificity, relative to PAK1.

[0330] The 134 amino acid collagen-like region of human PAK5 shares 34% amino acid identity to pro- α I type collagen from several species and is not present in other known PAKs.

[0331] The 265 amino acid catalytic domain of human PAK5 is most related to human PAK4 (SEQ ID NO:29), *Drosophila melanogaster* PAK (AJ011578), C45B11.1b from *C. elegans* (Z74029), and human PAK3 (Q13177), sharing 78%, 80%, 61%, and 55% amino acid identity, respectively. PAK5 also contains the potential "TPY" regulatory phosphorylation site in its activation loop. This "TPY" motif is conserved in other STE20-related kinases, including ZC1, ZC2, ZC3, ZC4, GEK2, KHS2, SULU1, SULU3 and PAK4.

[0332] The 19 amino acid C-tail shares 80% amino acid identity to a PAK-like homologue identified from genomic DNA (AL031652). Furthermore, this C-terminal region of human PAK5 contains a sequence that is homologous to a G-protein beta subunit binding site (Leeuw, T. et al. Nature, 391, 191-195 (1998) hereby incorporated by reference herein in its entirety including any figures, tables, or drawings). PAK5 has, therefore, the potential to be activated by both, Cdc42 as well as G-protein-dependant pathways.

V. Antibodies, Hybridomas, Methods of Use and Kits for Detection of STE20-Related Kinases

[0333] The present invention relates to an antibody having binding affinity to a kinase of the invention. The polypeptide may have the amino acid sequence set forth in SEQ ID NO:5, SEQ ID NO:6, SEQ ID NO:7, SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, SEQ ID NO:18, SEQ ID NO:22, SEQ ID NO:23, SEQ ID NO:24, SEQ ID NO:29, SEQ ID NO:97, SEQ ID NO:99, SEQ ID NO:101, SEQ ID NO:103, SEQ ID NO:105, or SEQ ID NO:107, or a functional derivative thereof, or at least 9 contiguous amino acids thereof (preferably, at least 20, 30, 35, or 40 or more contiguous amino acids thereof).

[0334] The present invention also relates to an antibody having specific binding affinity to a kinase of the invention. Such an antibody may be isolated by comparing its binding affinity to a kinase of the invention with its binding affinity to other polypeptides. Those which bind selectively to a kinase of the invention would be chosen for use in methods requiring a distinction between a kinase of the invention and other polypeptides. Such methods could include, but should not be limited to, the analysis of altered kinase expression in tissue containing other polypeptides.

[0335] The STE20-Related kinases of the present invention can be used in a variety of procedures and methods, such as for the generation of antibodies, for use in identifying pharmaceutical compositions, and for studying DNA/protein interaction.

[0336] The kinases of the present invention can be used to produce antibodies or hybridomas. One skilled in the art will recognize that if an antibody is desired, such a peptide could be generated as described herein and used as an immunogen. The antibodies of the present invention include monoclonal and polyclonal antibodies, as well fragments of these antibodies, and humanized forms. Humanized forms of the antibodies of the present invention may be generated using one of the procedures known in the art such as chimerization or CDR grafting.

[0337] The present invention also relates to a hybridoma which produces the above-described monoclonal antibody, or binding fragment thereof. A hybridoma is an immortalized cell line which is capable of secreting a specific monoclonal antibody.

[0338] In general, techniques for preparing monoclonal antibodies and hybridomas are well known in the art (Campbell, "Monoclonal Antibody Technology: Laboratory

Techniques in Biochemistry and Molecular Biology," Elsevier Science Publishers, Amsterdam, The Netherlands, 1984; St. Groth *et al.*, J. Immunol. Methods 35:1-21, 1980).

Any animal (mouse, rabbit, and the like) which is known to produce antibodies can be immunized with the selected polypeptide. Methods for immunization are well known in the art. Such methods include subcutaneous or intraperitoneal injection of the polypeptide. One skilled in the art will recognize that the amount of polypeptide used for immunization will vary based on the animal which is immunized, the antigenicity of the polypeptide and the site of injection.

[0339] The polypeptide may be modified or administered in an adjuvant in order to increase the peptide antigenicity. Methods of increasing the antigenicity of a polypeptide are well known in the art. Such procedures include coupling the antigen with a heterologous protein (such as globulin or β -galactosidase) or through the inclusion of an adjuvant during immunization.

[0340] For monoclonal antibodies, spleen cells from the immunized animals are removed, fused with myeloma cells, such as SP2/0-Agl4 myeloma cells, and allowed to become monoclonal antibody producing hybridoma cells. Any one of a number of methods well known in the art can be used to identify the hybridoma cell which produces an antibody with the desired characteristics. These include screening the hybridomas with an ELISA assay, western blot analysis, or radioimmunoassay (Lutz *et al.*, Exp. Cell Res. 175:109-124, 1988). Hybridomas secreting the desired antibodies are cloned and the class and subclass are determined using procedures known in the art (Campbell, "Monoclonal Antibody Technology: Laboratory Techniques in Biochemistry and Molecular Biology", *supra*, 1984).

[0341] For polyclonal antibodies, antibody-containing antisera is isolated from the immunized animal and is screened for the presence of antibodies with the desired specificity using one of the above-described procedures. The above-described antibodies may be detectably labeled. Antibodies can be detectably labeled through the use of radioisotopes, affinity labels (such as biotin, avidin, and the like), enzymatic labels (such as horse radish peroxidase, alkaline phosphatase, and the like) fluorescent labels (such as FITC or rhodamine, and the like), paramagnetic atoms, and the like. Procedures for accomplishing such labeling are well-known in the art, for example, *see Stemberger et al.*,

J. Histochem. Cytochem. 18:315, 1970; Bayer *et al.*, Meth. Enzym. 62:308-, 1979; Engval *et al.*, Immunol. 109:129-, 1972; Goding, J. Immunol. Meth. 13:215-, 1976. The labeled antibodies of the present invention can be used for *in vitro*, *in vivo*, and *in situ* assays to identify cells or tissues which express a specific peptide.

[0342] The above-described antibodies may also be immobilized on a solid support. Examples of such solid supports include plastics such as polycarbonate, complex carbohydrates such as agarose and sepharose, acrylic resins and such as polyacrylamide and latex beads. Techniques for coupling antibodies to such solid supports are well known in the art (Weir *et al.*, "Handbook of Experimental Immunology" 4th Ed., Blackwell Scientific Publications, Oxford, England, Chapter 10, 1986; Jacoby *et al.*, Meth. Enzym. 34, Academic Press, N.Y., 1974). The immobilized antibodies of the present invention can be used for *in vitro*, *in vivo*, and *in situ* assays as well as in immunochromatography.

[0343] Furthermore, one skilled in the art can readily adapt currently available procedures, as well as the techniques, methods and kits disclosed herein with regard to antibodies, to generate peptides capable of binding to a specific peptide sequence in order to generate rationally designed antipeptide peptides (Hurby *et al.*, "Application of Synthetic Peptides: Antisense Peptides", In Synthetic Peptides, A User's Guide, W.H. Freeman, NY, pp. 289-307, 1992; Kaspaczak *et al.*, Biochemistry 28:9230-9238, 1989).

[0344] Anti-peptide peptides can be generated by replacing the basic amino acid residues found in the peptide sequences of the kinases of the invention with acidic residues, while maintaining hydrophobic and uncharged polar groups. For example, lysine, arginine, and/or histidine residues are replaced with aspartic acid or glutamic acid and glutamic acid residues are replaced by lysine, arginine or histidine.

[0345] The present invention also encompasses a method of detecting a STE20-related kinase polypeptide in a sample, comprising: (a) contacting the sample with an above-described antibody, under conditions such that immunocomplexes form, and (b) detecting the presence of said antibody bound to the polypeptide. In detail, the methods comprise incubating a test sample with one or more of the antibodies of the present invention and assaying whether the antibody binds to the test sample. Altered levels of a kinase of the invention in a sample as compared to normal levels may indicate disease.

[0346] Conditions for incubating an antibody with a test sample vary. Incubation

conditions depend on the format employed in the assay, the detection methods employed, and the type and nature of the antibody used in the assay. One skilled in the art will recognize that any one of the commonly available immunological assay formats (such as radioimmunoassays, enzyme-linked immunosorbent assays, diffusion based Ouchterlony, or rocket immunofluorescent assays) can readily be adapted to employ the antibodies of the present invention. Examples of such assays can be found in Chard ("An Introduction to Radioimmunoassay and Related Techniques" Elsevier Science Publishers, Amsterdam, The Netherlands, 1986), Bullock *et al.* ("Techniques in Immunocytochemistry," Academic Press, Orlando, FL Vol. 1, 1982; Vol. 2, 1983; Vol. 3, 1985), Tijssen ("Practice and Theory of Enzyme Immunoassays: Laboratory Techniques in Biochemistry and Molecular Biology," Elsevier Science Publishers, Amsterdam, The Netherlands, 1985).

[0347] The immunological assay test samples of the present invention include cells, protein or membrane extracts of cells, or biological fluids such as blood, serum, plasma, or urine. The test samples used in the above-described method will vary based on the assay format, nature of the detection method and the tissues, cells or extracts used as the sample to be assayed. Methods for preparing protein extracts or membrane extracts of cells are well known in the art and can be readily be adapted in order to obtain a sample which is testable with the system utilized.

[0348] A kit contains all the necessary reagents to carry out the previously described methods of detection. The kit may comprise: (i) a first container means containing an above-described antibody, and (ii) second container means containing a conjugate comprising a binding partner of the antibody and a label. In another preferred embodiment, the kit further comprises one or more other containers comprising one or more of the following: wash reagents and reagents capable of detecting the presence of bound antibodies.

[0349] Examples of detection reagents include, but are not limited to, labeled secondary antibodies, or in the alternative, if the primary antibody is labeled, the chromophoric, enzymatic, or antibody binding reagents which are capable of reacting with the labeled antibody. The compartmentalized kit may be as described above for nucleic acid probe kits. One skilled in the art will readily recognize that the antibodies described in the present invention can readily be incorporated into one of the established kit formats

which are well known in the art.

VI. Isolation of Compounds Which Interact With STE20-Related Kinases

[0350] The present invention also relates to a method of detecting a compound capable of binding to a STE20-related kinase of the invention comprising incubating the compound with a kinase of the invention and detecting the presence of the compound bound to the kinase. The compound may be present within a complex mixture, for example, serum, body fluid, or cell extracts.

[0351] The present invention also relates to a method of detecting an agonist or antagonist of kinase activity or kinase binding partner activity comprising incubating cells that produce a kinase of the invention in the presence of a compound and detecting changes in the level of kinase activity or kinase binding partner activity. The compounds thus identified would produce a change in activity indicative of the presence of the compound. The compound may be present within a complex mixture, for example, serum, body fluid, or cell extracts. Once the compound is identified it can be isolated using techniques well known in the art.

[0352] The present invention also encompasses a method of agonizing (stimulating) or antagonizing kinase associated activity in a mammal comprising administering to said mammal an agonist or antagonist to a kinase of the invention in an amount sufficient to effect said agonism or antagonism. A method of treating diseases in a mammal with an agonist or antagonist of STE20-related kinase activity comprising administering the agonist or antagonist to a mammal in an amount sufficient to agonize or antagonize STE20-related kinase associated functions is also encompassed in the present application.

[0353] In an effort to discover novel treatments for diseases, biomedical researchers and chemists have designed, synthesized, and tested molecules that inhibit the function of protein kinases. Some small organic molecules form a class of compounds that modulate the function of protein kinases. Examples of molecules that have been reported to inhibit the function of protein kinases include, but are not limited to, bis monocyclic, bicyclic or heterocyclic aryl compounds (PCT WO 92/20642, published November 26, 1992 by Maguire *et al.*), vinylene-azaindole derivatives (PCT WO 94/14808, published

July 7, 1994 by Ballinari *et al.*), 1-cyclopropyl-4-pyridyl-quinolones (U.S. Patent No. 5,330,992), styryl compounds (U.S. Patent No. 5,217,999), styryl-substituted pyridyl compounds (U.S. Patent No. 5,302,606), certain quinazoline derivatives (EP Application No. 0 566 266 A1), seleoindoles and selenides (PCT WO 94/03427, published February 17, 1994 by Denny *et al.*), tricyclic polyhydroxylic compounds (PCT WO 92/21660, published December 10, 1992 by Dow), and benzylphosphonic acid compounds (PCT WO 91/15495, published October 17, 1991 by Dow *et al.*).

[0354] Compounds that can traverse cell membranes and are resistant to acid hydrolysis are potentially advantageous as therapeutics as they can become highly bioavailable after being administered orally to patients. However, many of these protein kinase inhibitors only weakly inhibit the function of protein kinases. In addition, many inhibit a variety of protein kinases and will cause multiple side-effects as therapeutics for diseases.

[0355] Some indolinone compounds, however, form classes of acid resistant and membrane permeable organic molecules. WO 96/22976 (published August 1, 1996 by Ballinari *et al.*) describes hydrosoluble indolinone compounds that harbor tetralin, naphthalene, quinoline, and indole substituents fused to the oxindole ring. These bicyclic substituents are in turn substituted with polar moieties including hydroxylated alkyl, phosphate, and ether moieties. U.S. Patent Application Serial Nos. 08/702,232, filed August 23, 1996, entitled "Indolinone Combinatorial Libraries and Related Products and Methods for the Treatment of Disease" by Tang *et al.* and 08/485,323, filed June 7, 1995, entitled "Benzylidene-Z-Indoline Compounds for the Treatment of Disease" by Tang *et al.* and International Patent Publication WO 96/22976, published August 1, 1996 by Ballinari *et al.*, all of which are incorporated herein by reference in their entirety, including any drawings, describe indolinone chemical libraries of indolinone compounds harboring other bicyclic moieties as well as monocyclic moieties fused to the oxindole ring. Applications 08/702,232, filed August 23, 1996, entitled "Indolinone Combinatorial Libraries and Related Products and Methods for the Treatment of Disease" by Tang *et al.*, 08/485,323, filed June 7, 1995, entitled "Benzylidene-Z-Indoline Compounds for the Treatment of Disease" by Tang *et al.*, and WO 96/22976, published August 1, 1996 by Ballinari *et al.* teach methods of indolinone synthesis, methods of testing the biological activity of

indolinone compounds in cells, and inhibition patterns of indolinone derivatives.

[0356] Other examples of substances capable of modulating kinase activity include, but are not limited to, tyrphostins, quinazolines, quinoxolines, and quinolines. The quinazolines, tyrphostins, quinolines, and quinoxolines referred to above include well known compounds such as those described in the literature. For example, representative publications describing quinazolines include Barker et al., EPO Publication No. 0 520 722 A1; Jones et al., U.S. Patent No. 4,447,608; Kabbe et al., U.S. Patent No. 4,757,072; Kaul and Vougioukas, U.S. Patent No. 5, 316,553; Kreighbaum and Comer, U.S. Patent No. 4,343,940; Pegg and Wardleworth, EPO Publication No. 0 562 734 A1; Barker et al., Proc. of Am. Assoc. for Cancer Research 32:327 (1991); Bertino, J.R., Cancer Research 3:293-304 (1979); Bertino, J.R., Cancer Research 9(2 part 1):293-304 (1979); Curtin et al., Br. J. Cancer 53:361-368 (1986); Fernandes et al., Cancer Research 43:1117-1123 (1983); Ferris et al. J. Org. Chem. 44(2):173-178; Fry et al., Science 265:1093-1095 (1994); Jackman et al., Cancer Research 51:5579-5586 (1981); Jones et al. J. Med. Chem. 29(6):1114-1118; Lee and Skibo, Biochemistry 26(23):7355-7362 (1987); Lemus et al., J. Org. Chem. 54:3511-3518 (1989); Ley and Seng, Synthesis 1975:415-522 (1975); Maxwell et al., Magnetic Resonance in Medicine 17:189-196 (1991); Mini et al., Cancer Research 45:325-330 (1985); Phillips and Castle, J. Heterocyclic Chem. 17(19):1489-1596 (1980); Reece et al., Cancer Research 47(11):2996-2999 (1977); Sculier et al., Cancer Immunol. and Immunother. 23:A65 (1986); Sikora et al., Cancer Letters 23:289-295 (1984); Sikora et al., Analytical Biochem. 172:344-355 (1988); all of which are incorporated herein by reference in their entirety, including any drawings.

[0357] Quinoxaline is described in Kaul and Vougioukas, U.S. Patent No. 5,316,553, incorporated herein by reference in its entirety, including any drawings.

[0358] Quinolines are described in Dolle et al., J. Med. Chem. 37:2627-2629 (1994); MaGuire, J. Med. Chem. 37:2129-2131 (1994); Burke et al., J. Med. Chem. 36:425-432 (1993); and Burke et al. BioOrganic Med. Chem. Letters 2:1771-1774 (1992), all of which are incorporated by reference in their entirety, including any drawings.

[0359] Tyrphostins are described in Allen et al., Clin. Exp. Immunol. 91:141-156 (1993); Anafi et al., Blood 82:12:3524-3529 (1993); Baker et al., J. Cell Sci. 102:543-555 (1992); Bilder et al., Amer. Physiol. Soc. pp. 6363-6143:C721-C730 (1991); Brunton et

al., Proceedings of Amer. Assoc. Cancer Rsch. 33:558 (1992); Bryckaert et al., Experimental Cell Research 199:255-261 (1992); Dong et al., J. Leukocyte Biology 53:53-60 (1993); Dong et al., J. Immunol. 151(5):2717-2724 (1993); Gazit et al., J. Med. Chem. 32:2344-2352 (1989); Gazit et al., " J. Med. Chem. 36:3556-3564 (1993); Kaur et al., Anti-Cancer Drugs 5:213-222 (1994); Kaur et al., King et al., Biochem. J. 275:413-418 (1991); Kuo et al., Cancer Letters 74:197-202 (1993); Levitzki, A., The FASEB J. 6:3275-3282 (1992); Lyall et al., J. Biol. Chem. 264:14503-14509 (1989); Peterson et al., The Prostate 22:335-345 (1993); Pillemer et al., Int. J. Cancer 50:80-85 (1992); Posner et al., Molecular Pharmacology 45:673-683 (1993); Rendu et al., Biol. Pharmacology 44(5):881-888 (1992); Sauro and Thomas, Life Sciences 53:371-376 (1993); Sauro and Thomas, J. Pharm. and Experimental Therapeutics 267(3):119-1125 (1993); Wolbring et al., J. Biol. Chem. 269(36):22470-22472 (1994); and Yoneda et al., Cancer Research 51:4430-4435 (1991); all of which are incorporated herein by reference in their entirety, including any drawings.

[0360] Other compounds that could be used as modulators include oxindolinones such as those described in U.S. patent application Serial No. 08/702,232 filed August 23, 1996, incorporated herein by reference in its entirety, including any drawings.

VII. Biological Significance, Applications and Clinical

Relevance of Novel STE20-Related Kinases

Human STLK2, STLK3, STLK4, STLK5, STLK6, and STLK7

[0361] STLK2, STLK4, STLK5, STLK6 and STLK7 belong to an expanding family of intracellular STKs that have varying degrees of sequence homology to SOK-1, a kinase implicated in oxidative stress agents (Pombo, CM et al, EMBO J. (17) 4537-4546, 1996). Our data shows that STLK2 is expressed highly in hematopoietic cells. Therefore, STLK2 may participate in the oxidative response pathway during inflammation. In addition, STLK2 could also be a possible component in the signaling pathways leading to T cell activation. High levels of STLK2 in several tumor cell lines could also imply that STLK2 might be involved in tumorigenesis.

[0362] STLK2 is most closely related to two human STE20-subfamily kinases: MST3 and SOK-1. MST3 is a 52,000 daltons cytoplasmic kinase that is ubiquitously

expressed with its highest levels of expression found in heart, skeletal muscle and pancreas. The serine/threonine kinase activity of MST3 is activated by phosphorylation. Unlike SOK-1, MST3 prefers Mn^{++} over Mg^{++} and can use both GTP and ATP as phosphate donors. MST3 may undergo dimerization. No agonists have yet been identified that activate MST3. The downstream signaling mechanism of this kinase is unknown (Schinkmann, K and Blenis, J. (1997) *J. Biol. Chem.* 272, 28695-28703).

[0363] SOK-1 is a 50,000 daltons cytoplasmic kinase expressed predominantly in testis, large intestine, brain and stomach and to a lesser extent in heart and lung. SOK-1 is also expressed in the germinal center B-cell line (RAMOS) and in a mature B cell line (HS Sultan). The serine/threonine kinase activity of SOK-1 is activated by phosphorylation. The C-terminus of SOK-1 has been shown to be inhibitory to the catalytic activity of this kinase. The only agonists known to activate SOK-1 are oxidant agents, like H_2O_2 and menadione, a quinone that is a potent intracellular generator of reactive oxygen species (Pombo, C.M. *et al.* *EMBO J.* 15, 4537-4546). SOK-1 is also activated by chemical anoxia through the generation of reactive oxygen species and release of calcium into the cytoplasm from intracellular stores. SOK-1, therefore, may play an important role in ischemia, the cause of myocardial infarction, stroke and acute renal failure (Pombo, C.M. *et al.* *J. Biol. Chem.* 272, 29372-29379 (1997)). The activity of SOK-1 in the response to oxidant stress is inversely correlated with the activity of the stress-activated protein kinases (SAPKs): elevated SOK-1 activity correlates with absent SAPK activity and vice-versa. SOK-1 does not activate any of the four MAP kinase pathways, SAPKs, p38, ERK-1 or MEK-5/ERK-5 (Pombo, C.M. *et al.* *EMBO J.* 15, 4537-4546). The downstream signaling mechanism of this kinase remains unknown.

[0364] STLK2 is expressed in a wide variety of immune cell types and tissues including thymus, dendrocytes, mast cells, monocytes, B cells (primary, Jurkat, RPMI, SR), T cells (CD8/CD4+, TH1, TH2, CEM, MOLT4) and megakaryocytes (K562), whereas STLK3 is restricted to thymus and STLK4 is predominately expressed in thymus, T cells (CD4/CD8+, TH1, CEM) and B cells (Jurkat, RPMI). Consequently, these STKs might participate in the oxidative response pathway during inflammation, reperfusion injury (stroke, surgery, shock), $TNF\alpha$ -mediated signaling, insulin desensitization, atherogenesis, vascular injury, T or B cell costimulation, or alternatively, participate in

other MAPK-related signal transduction processes.

[0365] STK5 is more distantly related to this STE20-subfamily including SOK-1 and STK2, STK3 and STK4. STK5, may therefore mediate a signaling pathway that is distinct from the oxidative stress response pathway.

[0366] The high degree of sequence homology in the C-termini of SOK-1, STK2, STK3, STK4, STK5, and STK6 raises the possibility that these novel STKs, like SOK-1, may be subject to autoinhibition through a conserved C-terminal motif.

Human ZC1, ZC2, ZC3 and ZC4

[0367] ZC1 is a good candidate for any disease in which tyrosine kinase, cytokine, or heterotrimeric G-protein coupled receptors have been implicated. The mouse homologue binds to NCK, and is recruited to activated PDGF (Su et al., EMBO 16: 1279-1290, 1997). The Drosophila homolog has been shown to bind to TRAF2, implicating it in TNF- α signaling (Liu et al., (1999) Curr. Biol. 9:101-104, 1999)). While ZC1 does not contain the exact NCK- and TRAF2-binding domains, it is likely to bind to related proteins.

[0368] Of the ZC subfamily of STE20-related protein kinases, ZC1 has very broad over-expression in many tumor types, suggesting that it may be involved in cellular growth, transformation, or tumor progression. A truncated form of ZC1 containing only the C-terminal putative MEKK1-binding domain was found to reduce the number of foci generated by H-Ras-V12 in Rat Intestinal Epithelial cells (RIE-1). These data indicate that ZC1 may play a role in the ability for these cells to overcome contact inhibition and anchorage-dependent growth.

[0369] The ZC1 homolog, Misshapen (*msn*) in *Drosophila melanogaster* was cloned as a result of complementing a mutation in a developmental pathway required for dorsal closure, a process involving changes in cell shape and position in the embryo (Treisman et al. Gene 186 119-125, 1997). A *D. melanogaster* homolog of the JNK1/JNK2 kinases from mammals was shown to function downstream of *msn* in the dorsal-closure signaling pathway (Su et al. Genes Dev. 12:2371-2380, 1998).

[0370] While ZC1 could be involved in multiple aspects of tumorigenesis, by analogy with *Drosophila*, the role of misshapen in dorsal closure suggests a critical role in

the regulation of the cytoskeleton for the processes of cell attachment, cell movement and perhaps migration.

[0371] The association of the ZC1 family members *msn* and NIK with TRAF2 may indicate a role for this kinase in cell survival and/or in apoptosis. The ZC1 family contains a highly conserved domain that in the mouse homolog, NIK, has been shown to bind to MEKK1 (Mitogen-activated/ Extracellular-regulated Kinase Kinase 1) (Su et al., (1997) EMBO 16(6): 1279-90). MEKK1 is involved in cell survival and/or apoptosis in several systems (Schlesinger et al., Front. Biosci.3:D1181-6, 1998). Depending on the context, MEKK1 appears to be upstream of either the ERK1/MAPK or the JNK/SAPK pathway [Schlesinger et al., (1998 Front. Biosci. 3:D1181-6). Three homologues of ZC1: murine NIK (NCK-interacting kinase)(Su et al.EMBO 16:1279-90, 1997), *Drosophila msn* (Liu et al.Curr. Biol. 9:101-104, 1999) and human HGK (HPK/GCK-like kinase)(Yao et al., J. Biol. Chem. 274:2118-25, 1999) have all been shown to activate the JNK pathway when over-expressed in 293T cells.

[0372] ZC1 shares a high degree of homology with these other family members in both the kinase domain and the "MEKK"-binding domains, yet it differs in the intervening region, which contains several putative binding domains for upstream signaling adapter molecules (e.g. NCK, TRAF2). Unlike the other family members, ZC1 does not appear to activate the JNK pathway in 293T cells as seen by its ability to induce expression of either a JUN or ATF2-driven luciferase gene. Upon co-transfection into these cells with HA-tagged JNK, modest activation of JNK was detected. ZC1 also modestly activated co-transfected ERK1. Both the ERK and the JNK activation were very slight compared with the positive controls in the assay (activated forms of MEK1 and MEKK1, respectively). In both cases, activation required the full-length kinase. While the kinase domain alone is up to 5x more active in autophosphorylation and in phosphorylation of MBP, it does not lead to activation of these potential downstream kinases. Based on the strong sequence homology of ZC1 with the other family members, it is very likely that ZC1 will be important for either JNK or ERK activation once the proper context is found.

[0373] ZC1 profoundly inhibits ERK1 kinase expression in co-transfection assays. This effect is dependent on ZC1 kinase activity, occurring with the wild-type and the kinase domain alone, but not with the kinase-dead mutant even though all three forms of

ZC1 are expressed at similar levels. This may suggest a role for this kinase in transcriptional or post-transcriptional regulation.

[0374] ZC1 may be an important component in the signaling pathways mediated by the co-stimulatory receptor CD28 in T cells and/or by the pro-inflammatory cytokine TNF α , since co-transfection of the wild-type ZC1 activated the RE/AP-luciferase and NF κ B-luciferase reporter genes. While our data showed that ZC1 strongly activates NF κ B in T-cells, no activation of NF κ B driven luciferase was detectable in NIH 3T3 cells. A recent paper (J. Biol. Chem. 274:2118-25; 1999.) has shown that a human ZC1 splicing isoform, HGK, is involved in the TNF α -signaling pathways.

[0375] Given the importance of T cell activation in autoimmunity and transplantation, as well as the key role that TNF α plays in inflammatory diseases, it is possible that ZC1 could be a therapeutic target for immunological diseases which include but are not limited to: rheumatoid arthritis, chronic inflammatory bowel diseases (ie Crohn's disease), chronic inflammatory pelvic disease, multiple sclerosis, asthma, osteoarthritis, psoriasis, atherosclerosis, rhinitis, and autoimmunity as well as organ transplantation and cardiovascular diseases.

[0376] ZC1 appears to be the human orthologue of murine NIK and possibly an orthologue of a *C. elegans* STE20-subfamily kinase encoded by the ZC504.4 cosmid.

[0377] Murine NIK is a 140,000 daltons kinase that is most highly expressed in brain and heart. NIK interacts with the SH3 domains of the adaptor molecule Nck through its proline-rich regions found in the C-terminal extra-catalytic region. The specific regions that mediate this interaction are two PxxP (SEQ ID NO: 148) motifs that are nearly uniformly conserved between NIK, ZC1,2,3 and the *C. elegans* STE20 ZC504.4 kinase. In addition, NIK binds MEKK1 through its 719 amino acid C-terminal (Su, Y-C. *et al.* (1997) EMBO J. 16, 1279-1290). MEKK1 is a membrane-associated kinase responsible for activating MKK4 (also known as SEK1), which in turn activates SAPK (Yan, M *et al.* (1994) Nature, 372, 798-800). NIK may function as a kinase that links growth factor activated pathways and the stress-response pathway mediated by SAPKs. According to this hypothesis, activation of growth factor receptors leads to receptor tyrosine phosphorylation, Nck binding to the phosphorylated tyrosines via its SH2 domain, NIK redistribution to a membrane compartment via binding to the SH3 domain of Nck, and

juxtaposition to the membrane-associated MEKK1. The NIK-MEKK1 interaction would, in this fashion, turn on the SAPK pathway in response to growth factor stimulation (Su, Y-C. *et al.* (1997) EMBO J. 16, 1279-1290).

[0378] Given the high homology between ZC1, ZC2, ZC3, and ZC4 STKs and NIK, it is conceivable that these kinases may each function to connect growth factor- and stress-activated signaling pathways. The heterogeneity that the ZC kinases exhibit within their putative SH3-binding domain could provide signaling specificity in terms of the nature of the adaptor molecule that they bind. The high level of sequence conservation in the C-termini of the ZC1, ZC2 and ZC3 strongly suggests that these human kinases, like murine NIK, also may bind to MEKK1 and activate SAPKs. The ZC kinases also display strong homology at their C-termini to protein domains that bind small GTPase proteins such as Rab, Rho and Rac. For example, the C-termini of ZC1 is 36.2% identical to citron, a murine Rho-binding protein, and 23.1% identical to the rab-binding region of GC kinase. This suggests that, in addition to adaptor molecules, small GTPase proteins may also mediate membrane association and activation of the ZC kinases. The presence of a potential coiled-coil region located immediately C-terminal to the catalytic region strongly suggests that the ZC kinases may also be subject to regulation via homo or heterodimerization events.

[0379] The *C. elegans* STE20 ZC504.4 kinase is the product of the mig-15 gene. The product of this gene has been implicated in several developmental processes such as epidermal development, Q neuroblast migrations and muscle arm targeting in the developing worm (Zhu, X. and Hedgecock E. (1997) Worm Breeder's Gazette 14, 76). The high level of sequence conservation between the ZC kinases and the ZC504.4 *C. elegans* kinase will make *C. elegans* a valuable model organism to study, through epistatic analysis, the signaling properties of the human ZC kinases.

Human KHS2

[0380] KHS1 (kinase homologous to SPS1/STE20) is a 100,000 dalton cytoplasmic STK that is expressed ubiquitously. KHS1 has been implicated in the mechanism of SAPK activation in response to inflammatory cytokines such as TNF α as well as to ultraviolet light, which also uses the TNF signaling pathway. TNF α binding

to its receptors (TNFR1 and TNFR2) results in the sequential association with the receptor C-tail of multiple signaling molecules including TNFR1-associated death domain protein (TRADD), Fas-associated death domain protein (FADD or MORT1), TNFR-associated factor 2 (TRAF2), and the STK RIP (receptor interacting protein). The TRADD-TRAF2 interaction is mediated by a conserved region present at the C-terminus of TRAF2, the TRAF domain. Activation of the NF κ B and SAPK pathways is mediated by the ring finger motif present at the N-terminus of TRAF2 (Curr. Opin. in Cell. Biol. (1997) 9:247-251). KHS1 is activated by TNF α stimulation in a TRAF2-dependant manner and inhibition of KHS1 blocks TNF α -induced SAPK activation but not NF κ B activation. The mechanism by which TRAF2 activates KHS1 is not known. Cotransfection of TRAF2- and KHS1-expressing constructs in 293T cells failed to reveal a direct association between these two molecules. KHS1 activates the SAPK pathway by a direct association with the constitutively active kinase MEKK1. MEKK1 subsequently activates SEK1, which in turn activates SAPK. Neither the MAPK nor the p38 kinase pathways are activated by KHS1 (Shi, C-S and Kehrl. J.H. (1997) J. Biol. Chem. 272, 32102-32107). In addition to its catalytic domain, downstream signaling of KHS1 requires its conserved C-terminus (Diener, K. *et al* (1997) Proc. Natl. Acad. Sci. 94, 9687-9692).

[0381] GCK (germinal center kinase) is a constitutively active 97,000 dalton STK that is broadly expressed. GCK may participate in B-cell differentiation since its expression is localized to the germinal center within lymphoid follicles. GCK activates the SAPK pathway in response to TNF α via activation of SEK1. The upstream activators of GCK in response to cytokines as well as the immediate downstream target of this kinase are unknown. The C-terminus of GCK is sufficient to activate SEK1 (Pombo, C.M. *et al* (1995) Nature, 377, 750-754).

[0382] The murine orthologue of GCK, rab8ip (rab8-interacting protein), is a 97,000 dalton protein that fractionates with both the soluble cytoplasmic fraction as well as with a salt-sensitive fraction associated with the basolateral membrane of the trans-Golgi region in polarized MDCK epithelial cells. The C-terminus of rab8ip binds to rab8, a small GTP-binding protein required for vesicular transport from the Golgi apparatus (Ren, M. *et al*. (1996) Proc. Natl. Acad. Sci. 93, 5151-5155). In addition to inducing the transcriptional activation of cytokines like IL2 via SAPK, GCK may also promote the rab-

dependent release of secretory proteins in response to $\text{TNF}\alpha$ (Buccione, R. *et al* (1995) Mol. Bio. Cell 6, 291).

[0383] HPK1 (hematopoietic protein kinase) is a constitutively active 90,000 dalton STK restricted to hematopoietic cells. HPK1 activates the SAPK pathway by directly binding to and activating MEKK1 (Hu, M. *et al* (1996) Genes and Dev. 10:2251-2264) as well as the ubiquitously expressed mixed-lineage kinase MLK-3 (Kiefer, F. *et al* (1996) EMBO J. 15:7013-7025). This function of HPK1 requires, in contrast to GCK, both its kinase domain as well as its C-terminus. The upstream activators of HPK1 remain unknown. HPK1 also plays a key role as a mediator of transforming growth factor- β - (TGF β) signaling. HPK1 activates the TGF β -activated kinase (TAK), which in turn stimulates the SAPK pathway by phosphorylating SEK1 (Wang W. *et al* (1997) J. Biol. Chem. 272:22771-22775).

[0384] KHS2 is expressed in thymus, dendrocytes and monocytes. KHS2 could have a complementary function to that of KHS1 as a mediator of SAPK activation in the cellular response to inflammatory cytokines. KHS2 could have the potential to interact directly with TRAF2 since a STK with the predicted molecular weight of KHS2 (approximately 101,000 daltons) is found in the TNFR-TRAF2 complex upon TNF α stimulation (VanArsdale, T. and Ware, C.F. (1994) J. Immunol. 153, 3043-3050). The presence of a putative binding domain for Rab or a Rab-like molecule at the C-terminus of KHS2 indicates that KHS2, in addition to having a potential role in the TRAF2-dependant TNF α cytokine response, could also mediate signaling events that utilize small GTPase proteins. Alternatively, the binding of a small GTPase protein to the C-terminus of KHS2 may be required for its potential TRAF2-dependant signaling to a downstream kinase such as MEKK1.

Human GEK2, SULU1 and SULU3

[0385] A recent report (Y-W Qian et al., Science 282:1701-1704,1998) described xPlkk1 as the activator of Plx1 (the Xenopus Polo kinase). In Xenopus oocytes, the STK Plkk1 can phosphorylate and activate Plx1 STK (the mammalian Polo kinase or PLK). A dominant-negative (kinase-dead) form of xPlkk1 prevents Plx1 activation and delays germinal vesicle breakdown. Yet another unidentified kinase is probably responsible for

xPlkk1 activation during mitosis.

[0386] The homology through the entire length of the xPlkk1 protein with GEK2 suggests that GEK2 might represent the human homologue for xPlkk1. Based on this, GEK2 might be upstream of PLK in mammalian cells. In addition, based on the phage display screen results using the SULU1 coiled-coil2 domain as bait, SULU1 might also interact in vivo with GEK2 and therefore regulate GEK2 (and/or SLK through the coiled-coil domain) activation leading to PLK activation and mitosis.

[0387] If such a cascade of events is required for mitosis in mammalian cells, interruption of this signaling cascade at any point might block mitosis and could be beneficial for cancer treatment.

[0388] A recently cloned STE20-subfamily kinase, rat TAO1, is most likely the rodent orthologue of human SULU3 (Hutchinson, M. *et al.* J. Biol. Chem 273:28625-28632, 1998). TAO1 activates MEK3, 4 and 6 in vitro, while in transfected cells it associates and activates only MEK3, resulting in phosphorylation and activation of p38. These results implicate TAO1 (SULU3) in the regulation of the p38 containing stress-responsive MAP kinase pathway.

[0389] Human SULU1 is weakly expressed in hematopoietic sources whereas SULU3 is found in B-cells and TH1-restricted T cells. These mammalian SULU STKs display strong homology to the *C. elegans* SULU kinase. The role that this kinase plays in nematode development is unknown. The strong sequence homology between the catalytic domain of mammalian SULU kinases and other STE20-subfamily kinases such as SOK-1 (human STE20) and KHS2 suggests that the mammalian kinases may participate in the stress-response pathway. The potential coiled-coil domains found at the C-terminus of the SULU kinases may play a role in the regulation of this kinase.

[0390] Murine LOK (lymphocyte-oriented kinase) is a constitutively activated STK of approximately 130,000 daltons that is predominantly expressed in spleen, thymus and bone marrow (Kuramochi, S. *et al* (1997) J. Biol. Chem. 272: 22679-22684) as well as in meiotic testicular and primordial germ cells. The LOK1 gene is located in chromosome 11 of the mouse near the *wr* locus, a region that is associated with reproductive and neurological defects (Yanagisawa, M. *et al* (1996) Mol. Reprod. and Dev. 45:411-420). LOK does not activate any of the known MAPK pathways (ERK, JNK and p38) nor the NFkB pathway. The upstream signaling elements of LOK as well as the extracellular stimuli that utilize this kinase to elicit a biological response are also unknown (Kuramochi, S. *et al* (1997) J. Biol. Chem. 272: 22679-22684).

[0391] Human GEK2 is highly related to murine LOK, but based on sequence divergence in the non-catalytic domain, it appears to be a distinct member of this STE20-subfamily. GEK2 may signal through a pathway that remains to be defined. The presence of potential coiled-coil regions at the C-terminus of GEK2 could play a key role in regulating the functions of this kinase.

Human PAK4 and PAK5

[0392] The p21 activated protein kinases (PAK) are a closely related subgroup of the STE20 family of serine/threonine kinases. Extensive genetic and biochemical analysis of the budding yeast STE20 has shown the critical role this serine/threonine kinase plays at the juncture of several important intracellular pathways required to appropriately respond to extracellular signals. STE20 links the transcriptional response by mediating the activation of the appropriate downstream MAPK pathway as well as coupling changes in cellular morphology via its control of the actin cytoskeleton.

[0393] A hallmark of the PAK subgroup is their small G protein-binding domain (PBD) that confers G protein-dependent activation upon this group of kinases. Via the PBD, PAKs bind to activated small G proteins resulting in the derepression of the PAK's intrinsic kinase activity.

[0394] Until recently, there were three known PAK kinases: PAK1, a 68 kD protein whose expression is restricted expression to brain, muscle, and spleen; PAK2 (PAK1, PAK65), a 62 kD protein whose expression is ubiquitous; and PAK3, a 65kD

protein whose expression is restricted to the brain. Similar to STE20, the mammalian PAKs (1,2, and 3) have been shown to respond to extracellular signals (growth factors, mitogens, cytokines and a variety of cellular stresses) (Bagrodia, *et al.* (1995). *J. Biol. Chem.* 270: 22731-22737; Zhang, S., *et al.* (1995). *J. Biol. Chem.* 270: 23934-23936, Frost, J. *et al.* (1998) *J. Biol. Chem.* 273: 28191-28198; Galisteo, M. *et al.* (1996) *J. Biol. Chem.* 271: 20997-21000), and are linked to TCR activation (Yablonski, D., *et al.* (1998) *EMBO J.* 17: 5647-5657), and heterotrimeric G protein-coupled receptors (Knaus, U. *et al.* (1995) *Science* 269: 221-223).

[0395] The PAKs were originally identified as effectors for members of the Rho family of small G proteins (such as Rac and Cdc42), hence their name, p21-activated kinases (PAK) (Manser *et al.* *Nature* 367:40-46). The recruitment of the PAKs to the appropriate intracellular location is critical to their function. Attempts to elucidate the role played by PAKs in intracellular signaling and morphological changes is complicated due to the complex interactions by which they can be recruited by such factors as activated small G proteins (rac, cdc42), adaptors (nck) and exchange proteins (PIX, Cool).

[0396] The adaptor molecule, Nck, is constitutively bound via its SH3 domain to the proline-rich motif in the N-terminal portion of PAK1. Binding of the Nck-PAK complex to activated growth factor receptors in response to growth factor stimulation provides a mechanism to link growth factor-stimulated and stress-response pathways (Galisteo, M. *et al.* (1996) *J. Biol. Chem.* 271:20997-21000).

[0397] The PBD found at the N-terminus of PAK1 is responsible for its high-affinity interaction with the GTP-bound forms of Cdc42 and Rac (Burbelo, P. *et al.* (1995) *J. Biol. Chem.* 270:29071-29074). The exact mechanism through which the small GTPases activate PAKs may involve, in part, association of the kinase with activated growth factor receptors through guanine nucleotide exchange factors (GEFs). GEFs activate small GTPases by catalyzing the formation of their GTP-bound state, thereby promoting their association with, and activation of, PAKs. The known mammalian PAK kinases, as well as *Drosophila* and *C. elegans* PAKs, all conserve an N-terminal extracatalytic motif responsible for a high-affinity interaction with the GEF, PIX. The PAK-Cdc42 interaction and subsequent PAKs occurs as a PIX/PAK complex (Manser, E. *et al.* (1998) *Molecular Cell*, 1, 183-192).

[0398] PAK signaling stimulated by heterotrimeric G proteins is mediated through the interaction between a short conserved amino acid region located at the C-terminus of PAK1 with the G-protein β -subunit (Leeuw, T. *et al.* (1998) *Nature*, 391: 191-195).

[0399] A variety of studies have indicated that the human PAKs are involved in mediating the activation of stress-activated protein kinase pathways (JNK and to lesser extent p38). PAKs are also potential mediators in the crosstalk between the pathways regulated by the Rho family of small G proteins and the signaling pathways directly downstream of Ras leading to the activation of the ERK pathway (Bagrodia, *et al.* (1995). *J. Biol. Chem.* 270: 22731-22737; Zhang, S., *et al.* (1995). *J. Biol. Chem.* 270: 23934-23936; Brown, J., *et al.* (1996) *Curr Biol.* 6:598-60596; Frost, J., *et al.* (1996). *Mol. Cell. Biol.* 16: 3707-3713).

[0400] PAK1 has been implicated in phosphorylating a regulatory site in MEK1 that is necessary for MEK1's ability to interact with Raf1 (Frost, *et al.* (1997) *EMBO J.* 16:6426-6438). PAK3 has been shown to phosphorylate Raf1 on a site that is important for Raf1 activity (King, A., *et al.* (1998). *Nature* 396: 180-183).

[0401] PAKs play an important role in controlling morphological changes in cell shape mediated by the actin cytoskeleton. Such morphological changes are required for cellular functions ranging from cell division and proliferation to cell motility and vesicle transport. PAK activity has been implicated in the localized assembly (leading edge) and disassembly (retracting edge) of focal adhesions necessary for cell motility (Frost J. *et al.* (1998) *J. Biol. Chem.* 273:28191-28198).

[0402] PAK2 may have a role in the morphological changes induced during apoptosis (Membrane and morphological changes in apoptotic cells regulated by caspase-mediated activation of PAK2. (Rudel, T. (1997) *Science*. 276:1571-4)), and PAK1 may be important in preventing apoptosis (Faure S, *et al.* (1997) *EMBO J.* (1997) 16:5550-61). In addition to overcoming mitogen- and anchorage-independent growth, tumor cells need to escape the programmed cell death that accompanies deregulated cell growth. Thus, inhibition of PAKs may be effective in triggering apoptosis in tumors.

[0403] A direct requirement for PAKs in the transformation of mammalian cells has been shown for PAK1 and PAK2. Kinase-dead alleles of PAK1 block ras transformation of RAT1 and Schwann cells (Tang, Y., *et al.* (1997) *Mol. Cell. Biol.* 17,

4454-4464). Dominant-negative alleles of PAK2 have been shown to interfere with ras-mediated transformation of mammalian cells (Osada, S., (1997) FEBS Lett 404:227-233)

[0404] Mutations in PAK3 have been implicated in nonsyndromic X-linked mental retardation suggesting a role for PAK3 in cognitive function (Allen, K. *et al.* (1998) Nat. Genet. 20: 25-30). PAK1 has been implicated in neurite outgrowth in PC12 cells (Daniels, R. *et al.* (1998) EMBO J. 17: 754-764; Nikolic, M. *et al.* (1998) Nature 395:194-198).

[0405] Finally, PAK-like STKs may also play a role in AIDS pathogenesis since the myristoylated 27kD membrane-associated HIV Nef gene product directly interacts with and activates these kinases via cdc42 and Rac. The Nef-mediated activation of PAK-like STKs correlates with the induction of high viral titers and the development of AIDS in infected hosts (Cullen, B. R. (1996) Curr. Biol. 6:1557-1559).

[0406] Our results show that PAK4 is expressed in thymus, dendrocytes, mast cells, monocytes, as well as in T cells (TH2-restricted cells and MOLT4) and the B cell line RPMI. PAK5 is found in mast cells and in the T cell line MOLT4. These data suggest potential roles for PAK4 and PAK5 in the immune system.

[0407] PAK4 and PAK5 share with the known PAKs a potential cdc42-binding motif at their N-termini. Both PAK4 and PAK5 display sequence homology in their C-termini to a motif responsible for an interaction between PAK1 and the β -subunit of heterotrimeric G-proteins (amino acid residues 665-676 in PAK 4, and amino acid residues 386-398 in PAK5). Consequently, PAK4, and possibly PAK5, could mediate signaling events originating from growth factors as well as from ligands that stimulate G-protein-linked receptors.

[0408] PAK4 conserves a leucine (leu 44), that when mutated to a phenylalanine renders the kinase activity of human PAK1 constitutively active, bypassing its cdc42-binding requirement for activation (Brown J. *et al* (1996) Current Biol. 6:598-605). PAK5 contains an isoleucine at the equivalent position. Therefore, the mechanism by which cdc42 potentially activates human PAK1, PAK4, and possibly PAK5, may be very similar.

[0409] PAK4 and PAK5 however, lack the PIX-binding motif, and consequently cdc42-activating GEFs other than PIX (for example Dbp and Cdc25) must be responsible for the activation of these kinases. Alternatively, PAK4 and PAK5 may be activated by another GTPase, such as Rac1 which uses the Tiam1 GEF for its activation to the GTP-

bound state.

[0410] PAK4 and PAK5 also lack the PxxP (SEQ ID NO: 148) motif responsible for the Nck-PAK1 association. Between the PBD or cdc42-binding N-terminal motifs and the putative GEF-binding regions, PAK4 and PAK5 have long insertions (185 and 123 amino acids for PAK4 and PAK5, respectively) relative to PAK1. This region probably confers different binding characteristics to adaptor molecules and/or GEFs from those exhibited by known mammalian PAKs.

[0411] PAKs have been shown to be upstream in pathways leading to activation of both the JNK (Bagrodia, S., *et al.* (1995) J. Biol. Chem. 270: 22731-22737) and ERK kinase pathways (Brown, J., *et al.* (1996). Curr Biol. 6:598-605). PAK1 was shown to synergize with ras in activation of the ERK pathway through phosphorylation of MEK1 (Frost, J. *et al.* (1997). EMBO J. 16:6426-6438). Our data shows that MEK1 serves as an *in vitro* substrate for PAK4, suggesting a potential role for PAK4 in the activation of the ERK pathway and mitogenesis.

[0412] PAK5 may also have a mitogenic role, and be linked to cancer, based on its expression profile (elevated RNA and protein levels in a wide variety of tumor cell lines), its interaction with cdc42 via its PBD, and the ability of a kinase-dead allele (Lys350, 351 Ala) to block ras transformation of NIH3T3 cells. Thus, a screen for small molecule inhibitors of PAK5 kinase activity may yield compounds with therapeutic potential for intervention in cancer derived from a wide variety of tissue types.

[0413] PAK4 and PAK5 may also play a role in HIV pathogenesis as potential mediators of Nef signaling, since none of the known PAKs correspond to the PAK-like kinase shown to interact with, and be activated by, the HIV nef protein (Lu, X. *et al.* (1996) Current Biology 6:1677-1684)

[0414] The 3' untranslated region of PAK4 contains a CA repeat that is prone to undergo expansion. CA dinucleotide repeat instability has been associated with disease (Toren, M.Z. *et al* (1998) Am. J. Hematol. 57: 148-152), and expansion of such repeat in the 3' untranslated region of PAK4 could implicate this kinase in as yet unknown pathologies.

Clinical applications

Human STLK2, STLK3, STLK4, STLK5, STLK6, and STLK7

[0415] STLK3, STLK5, STLK6 and STLK7, as well as other homologues of the STLK subfamily of STE20 protein kinases such as STLK4, may play an important role as mediators of the immune response. Thus, they are targets for the development of specific small molecule inhibitors to treat immunological diseases, including, but not limited to, rheumatoid arthritis, chronic inflammatory bowel diseases (e.g. Crohn's disease), chronic inflammatory pelvic disease, multiple sclerosis, asthma, osteoarthritis, psoriasis, atherosclerosis, rhinitis and autoimmunity, as well as in organ transplantation. Other diseases include cardiovascular diseases.

[0416] The human STLKs may also play an important role in cell growth regulation. Thus, they are targets for developing small molecule kinase inhibitors for the treatment of cancer and metastases. STLK5 maps to a chromosomal region frequently amplified in a variety of tumors including those from non-small cell lung cancer, breast cancer and peripheral nerve tumors. This suggests that STLK5 could play a role in the development, maintenance, or progression of human tumors.

[0417] The potential role of human STLKs 2,3, and 4 in mediating oxidative stress strongly suggests that drugs targeting these kinases could prove useful in the treatment of myocardial infarction, arrhythmia and other cardiomyopathies, stroke, renal failure, oxidative stress-related neurodegenerative disorders such amyotrophic lateral sclerosis, Parkinson's disease and Leigh syndrome, a necrotizing mitochondrial encephalopathy, as well.

Human ZC1, ZC2, ZC3, and ZC4

[0418] ZC1 may be a component of the CD28-signaling pathway and therefore important in T cell activation. As such, ZC1 as well as other ZC subfamily kinases, are targets for the development of specific small molecule inhibitors to treat immunological diseases, including, but not limited to, rheumatoid arthritis, chronic inflammatory bowel diseases (e.g. Crohn's disease), chronic inflammatory pelvic disease, multiple sclerosis, asthma, osteoarthritis, psoriasis, atherosclerosis, rhinitis and autoimmunity, as well as organ transplantation. Other diseases include cardiovascular diseases.

[0419] ZC1 and ZC2 are also implicated in cell growth regulation. Thus, ZC

subfamily kinases are targets for developing small molecule inhibitors for the treatment of cancer and metastases. ZC2 maps to a chromosomal region frequently amplified in a variety of tumors including those from non-small cell lung cancer, small cell lung cancer, and cervical cancer. This suggests that ZC2 could play a role in the development, maintenance, or progression of human tumors.

[0420] The role of human ZC1, ZC2, ZC3, and ZC4 in the inflammatory and stress-response pathways, strongly suggests that drugs targeting these kinases could have strong immunosuppressive actions. These drugs can prove valuable for the treatment of rheumatoid arthritis, atherosclerosis, autoimmune disorders and organ transplantation among others. At least one very important class of immunosuppressants, corticosteroids, functions by blocking SAPK activation at an as yet undefined site on this pathway (Swanek, J.L. *et al* (1997) *Mol. Cell. Biol.* (1997) 6274-6282). Other immunosuppressive drugs like the pyridinyl imidazoles specifically target the p38 kinases (Kumar, S. *et al* (1997) *Biochem. Biophys. Res. Commun.* 235: 533-528). Drug targeting of the MAPK and p38 pathways could lead to the development of novel immunosuppressants.

Human SULU and GEK

[0421] The potential role of these novel STE20-related protein kinases in the control of mitosis strongly suggests that agents that specifically inhibit these kinases could be useful for cancer and metastases treatment.

[0422] The close homology of human STK5, GEK2, SULU1 and SULU3 to STE20-subfamily kinases involved in the stress and oxidative response pathway strongly suggests that drugs targeting these kinases may also be useful as immunosuppressants as well as to treat ischemic disorders.

Human KHS2

[0423] The role of human KHS2 in the inflammatory and stress-response pathways, strongly suggests that drugs targeting this and related kinases could have strong immunosuppressive actions. These drugs can prove valuable for the treatment of rheumatoid arthritis, atherosclerosis, autoimmune disorders and organ transplantation among others. At least one very important class of immunosuppressants, corticosteroids,

functions by blocking SAPK activation at an as yet undefined site on this pathway (Swanetek, J.L. *et al* (1997) Mol. Cell. Biol. (1997) 6274-6282). Other immunosuppressive drugs like the pyridinyl imidazoles specifically target the p38 kinases (Kumar, S. *et al* (1997) Biochem. Biophys. Res. Commun. 235: 533-528). Drug targeting of the MAPK and p38 pathways could lead to the development of novel immunosuppressants.

Human PAK family

[0424] PAK5 has a role in cancer based on its expression profile (elevated RNA and protein levels in wide variety of tumor lines), its interaction with Cdc42 via its PBD, and the ability of the kinase-dead allele of PAK5 (Lys350, 351Ala) to block ras transformation of NIH3T3 cells. Thus, a screen for small molecule inhibitors of PAK5 kinase activity may yield compounds with therapeutic potential for intervention in cancers and metastases derived from a wide range of tissue types.

[0425] PAK5 maps to a chromosomal region frequently amplified in a variety of tumors including those from non-small cell lung cancer, and small cell lung cancer. These findings suggest that PAK5 could play a role in the development, maintenance, or progression of human tumors and/or metastases.

[0426] The role of human PAK4, and PAK5 in the inflammatory and stress-response pathways also strongly suggests that drugs targeting these kinases could have strong immunosuppressive actions. These drugs can prove valuable for the treatment of rheumatoid arthritis, atherosclerosis, autoimmune disorders and organ transplantation among others. At least one very important class of immunosuppressants, corticosteroids, functions by blocking SAPK activation at an as yet undefined site on this pathway (Swanetek, J.L. *et al* (1997) Mol. Cell. Biol. (1997) 6274-6282). Other immunosuppressive drugs like the pyridinyl imidazoles specifically target the p38 kinases (Kumar, S. *et al* (1997) Biochem. Biophys. Res. Commun. 235: 533-528). Drug targeting of the MAPK and p38 pathways could lead to the development of novel immunosuppressants. In addition, drugs targeting PAK4 or PAK5 could prove useful as immunosuppressants as well as in AIDS treatment.

VIII. Transgenic Animals.

[0427] A variety of methods are available for the production of transgenic animals associated with this invention. DNA can be injected into the pronucleus of a fertilized egg before fusion of the male and female pronuclei, or injected into the nucleus of an embryonic cell (*e.g.*, the nucleus of a two-cell embryo) following the initiation of cell division (Brinster *et al.*, Proc. Nat. Acad. Sci. USA 82: 4438-4442, 1985). Embryos can be infected with viruses, especially retroviruses, modified to carry inorganic-ion receptor nucleotide sequences of the invention.

[0428] Pluripotent stem cells derived from the inner cell mass of the embryo and stabilized in culture can be manipulated in culture to incorporate nucleotide sequences of the invention. A transgenic animal can be produced from such cells through implantation into a blastocyst that is implanted into a foster mother and allowed to come to term. Animals suitable for transgenic experiments can be obtained from standard commercial sources such as Charles River (Wilmington, MA), Taconic (Germantown, NY), Harlan Sprague Dawley (Indianapolis, IN), etc.

[0429] The procedures for manipulation of the rodent embryo and for microinjection of DNA into the pronucleus of the zygote are well known to those of ordinary skill in the art (Hogan *et al.*, *supra*). Microinjection procedures for fish, amphibian eggs and birds are detailed in Houdebine and Chourrout (Experientia 47: 897-905, 1991). Other procedures for introduction of DNA into tissues of animals are described in U.S. Patent No., 4,945,050 (Sandford *et al.*, July 30, 1990).

[0430] By way of example only, to prepare a transgenic mouse, female mice are induced to superovulate. Females are placed with males, and the mated females are sacrificed by CO₂ asphyxiation or cervical dislocation and embryos are recovered from excised oviducts. Surrounding cumulus cells are removed. Pronuclear embryos are then washed and stored until the time of injection. Randomly cycling adult female mice are paired with vasectomized males. Recipient females are mated at the same time as donor females. Embryos then are transferred surgically. The procedure for generating transgenic rats is similar to that of mice (Hammer *et al.*, Cell 63:1099-1112, 1990).

[0431] Methods for the culturing of embryonic stem (ES) cells and the subsequent production of transgenic animals by the introduction of DNA into ES cells using methods such as electroporation, calcium phosphate/DNA precipitation and direct injection also are

well known to those of ordinary skill in the art (Teratocarcinomas and Embryonic Stem Cells, A Practical Approach, E.J. Robertson, ed., IRL Press, 1987).

[0432] In cases involving random gene integration, a clone containing the sequence(s) of the invention is co-transfected with a gene encoding resistance. Alternatively, the gene encoding neomycin resistance is physically linked to the sequence(s) of the invention. Transfection and isolation of desired clones are carried out by any one of several methods well known to those of ordinary skill in the art (E.J. Robertson, *supra*).

[0433] DNA molecules introduced into ES cells can also be integrated into the chromosome through the process of homologous recombination (Capecchi, *Science* 244: 1288-1292, 1989). Methods for positive selection of the recombination event (*i.e.*, neo resistance) and dual positive-negative selection (*i.e.*, neo resistance and gancyclovir resistance) and the subsequent identification of the desired clones by PCR have been described by Capecchi, *supra* and Joyner *et al.* (*Nature* 338: 153-156, 1989), the teachings of which are incorporated herein in their entirety including any drawings. The final phase of the procedure is to inject targeted ES cells into blastocysts and to transfer the blastocysts into pseudopregnant females. The resulting chimeric animals are bred and the offspring are analyzed by Southern blotting to identify individuals that carry the transgene. Procedures for the production of non-rodent mammals and other animals have been discussed by others (Houdebine and Chourrout, *supra*; Pursel *et al.*, *Science* 244:1281-1288, 1989; and Simms *et al.*, *Bio/Technology* 6:179-183, 1988).

[0434] Thus, the invention provides transgenic, nonhuman mammals containing a transgene encoding a kinase of the invention or a gene effecting the expression of the kinase. Such transgenic nonhuman mammals are particularly useful as an *in vivo* test system for studying the effects of introduction of a kinase, or regulating the expression of a kinase (*i.e.*, through the introduction of additional genes, antisense nucleic acids, or ribozymes).

[0435] A "transgenic animal" is an animal having cells that contain DNA which has been artificially inserted into a cell, which DNA becomes part of the genome of the animal which develops from that cell. Preferred transgenic animals are primates, mice, rats, cows, pigs, horses, goats, sheep, dogs and cats. The transgenic DNA may encode

human STE20-related kinases. Native expression in an animal may be reduced by providing an amount of anti-sense RNA or DNA effective to reduce expression of the receptor.

IX. Gene Therapy

[0436] STE20-related kinases or their genetic sequences will also be useful in gene therapy (reviewed in Miller, Nature 357:455-460, 1992). Miller states that advances have resulted in practical approaches to human gene therapy that have demonstrated positive initial results. The basic science of gene therapy is described in Mulligan (Science 260:926-931, 1993).

[0437] In one preferred embodiment, an expression vector containing STE20-related kinase coding sequence is inserted into cells, the cells are grown *in vitro* and then infused in large numbers into patients. In another preferred embodiment, a DNA segment containing a promoter of choice (for example a strong promoter) is transferred into cells containing an endogenous gene encoding kinases of the invention in such a manner that the promoter segment enhances expression of the endogenous kinase gene (for example, the promoter segment is transferred to the cell such that it becomes directly linked to the endogenous kinase gene).

[0438] The gene therapy may involve the use of an adenovirus containing kinase cDNA targeted to a tumor, systemic kinase increase by implantation of engineered cells, injection with kinase-encoding virus, or injection of naked kinase DNA into appropriate tissues.

[0439] Target cell populations may be modified by introducing altered forms of one or more components of the protein complexes in order to modulate the activity of such complexes. For example, by reducing or inhibiting a complex component activity within target cells, an abnormal signal transduction event(s) leading to a condition may be decreased, inhibited, or reversed. Deletion or missense mutants of a component, that retain the ability to interact with other components of the protein complexes but cannot function in signal transduction may be used to inhibit an abnormal, deleterious signal transduction event.

[0440] Expression vectors derived from viruses such as retroviruses, vaccinia

virus, adenovirus, adeno-associated virus, herpes viruses, several RNA viruses, or bovine papilloma virus, may be used for delivery of nucleotide sequences (*e.g.*, cDNA) encoding recombinant kinase of the invention protein into the targeted cell population (*e.g.*, tumor cells). Methods which are well known to those skilled in the art can be used to construct recombinant viral vectors containing coding sequences (Maniatis *et al.*, *Molecular Cloning: A Laboratory Manual*, Cold Spring Harbor Laboratory, N.Y., 1989; Ausubel *et al.*, *Current Protocols in Molecular Biology*, Greene Publishing Associates and Wiley Interscience, N.Y., 1989). Alternatively, recombinant nucleic acid molecules encoding protein sequences can be used as naked DNA or in a reconstituted system *e.g.*, liposomes or other lipid systems for delivery to target cells (*e.g.*, Felgner *et al.*, *Nature* 337:387-8, 1989). Several other methods for the direct transfer of plasmid DNA into cells exist for use in human gene therapy and involve targeting the DNA to receptors on cells by complexing the plasmid DNA to proteins (Miller, *supra*).

[0441] In its simplest form, gene transfer can be performed by simply injecting minute amounts of DNA into the nucleus of a cell, through a process of microinjection (Capecchi, *Cell* 22:479-88, 1980). Once recombinant genes are introduced into a cell, they can be recognized by the cell's normal mechanisms for transcription and translation, and a gene product will be expressed. Other methods have also been attempted for introducing DNA into larger numbers of cells. These methods include: transfection, wherein DNA is precipitated with CaPO_4 and taken into cells by pinocytosis (Chen *et al.*, *Mol. Cell Biol.* 7:2745-52, 1987); electroporation, wherein cells are exposed to large voltage pulses to introduce holes into the membrane (Chu *et al.*, *Nucleic Acids Res.* 15:1311-26, 1987); lipofection/liposome fusion, wherein DNA is packaged into lipophilic vesicles which fuse with a target cell (Felgner *et al.*, *Proc. Natl. Acad. Sci. USA.* 84:7413-7417, 1987); and particle bombardment using DNA bound to small projectiles (Yang *et al.*, *Proc. Natl. Acad. Sci.* 87:9568-9572, 1990). Another method for introducing DNA into cells is to couple the DNA to chemically modified proteins.

[0442] It has also been shown that adenovirus proteins are capable of destabilizing endosomes and enhancing the uptake of DNA into cells. The admixture of adenovirus to solutions containing DNA complexes, or the binding of DNA to polylysine covalently attached to adenovirus using protein crosslinking agents substantially improves the uptake

and expression of the recombinant gene (Curiel *et al.*, Am. J. Respir. Cell. Mol. Biol., 6:247-52, 1992).

[0443] As used herein "gene transfer" means the process of introducing a foreign nucleic acid molecule into a cell. Gene transfer is commonly performed to enable the expression of a particular product encoded by the gene. The product may include a protein, polypeptide, anti-sense DNA or RNA, or enzymatically active RNA. Gene transfer can be performed in cultured cells or by direct administration into animals. Generally gene transfer involves the process of nucleic acid contact with a target cell by non-specific or receptor mediated interactions, uptake of nucleic acid into the cell through the membrane or by endocytosis, and release of nucleic acid into the cytoplasm from the plasma membrane or endosome. Expression may require, in addition, movement of the nucleic acid into the nucleus of the cell and binding to appropriate nuclear factors for transcription.

[0444] As used herein "gene therapy" is a form of gene transfer and is included within the definition of gene transfer as used herein and specifically refers to gene transfer to express a therapeutic product from a cell *in vivo* or *in vitro*. Gene transfer can be performed *ex vivo* on cells which are then transplanted into a patient, or can be performed by direct administration of the nucleic acid or nucleic acid-protein complex into the patient.

[0445] In another preferred embodiment, a vector having nucleic acid sequences encoding a STE20-related kinase polypeptide is provided in which the nucleic acid sequence is expressed only in specific tissue. Methods of achieving tissue-specific gene expression are set forth in International Publication No. WO 93/09236, filed November 3, 1992 and published May 13, 1993.

[0446] In all of the preceding vectors set forth above, a further aspect of the invention is that the nucleic acid sequence contained in the vector may include additions, deletions or modifications to some or all of the sequence of the nucleic acid, as defined above.

[0447] In another preferred embodiment, a method of gene replacement is set forth. "Gene replacement" as used herein means supplying a nucleic acid sequence which is capable of being expressed *in vivo* in an animal and thereby providing or augmenting the

function of an endogenous gene which is missing or defective in the animal.

X. Administration of Substances

[0448] Methods of determining the dosages of compounds to be administered to a patient and modes of administering compounds to an organism are disclosed in U.S. Application Serial No. 08/702,282, filed August 23, 1996 and International patent publication number WO 96/22976, published August 1 1996, both of which are incorporated herein by reference in their entirety, including any drawings, figures, or tables. Those skilled in the art will appreciate that such descriptions are applicable to the present invention and can be easily adapted to it.

[0449] The proper dosage depends on various factors such as the type of disease being treated, the particular composition being used, and the size and physiological condition of the patient. Therapeutically effective doses for the compounds described herein can be estimated initially from cell culture and animal models. For example, a dose can be formulated in animal models to achieve a circulating concentration range that initially takes into account the IC_{50} as determined in cell culture assays. The animal model data can be used to more accurately determine useful doses in humans.

[0450] Plasma half-life and biodistribution of the drug and metabolites in the plasma, tumors, and major organs can be also be determined to facilitate the selection of drugs most appropriate to inhibit a disorder. Such measurements can be carried out. For example, HPLC analysis can be performed on the plasma of animals treated with the drug and the location of radiolabeled compounds can be determined using detection methods such as X-ray, CAT scan, and MRI. Compounds that show potent inhibitory activity in the screening assays, but have poor pharmacokinetic characteristics, can be optimized by altering the chemical structure and retesting. In this regard, compounds displaying good pharmacokinetic characteristics can be used as a model.

[0451] Toxicity studies can also be carried out by measuring the blood cell composition. For example, toxicity studies can be carried out in a suitable animal model as follows: 1) the compound is administered to mice (an untreated control mouse should also be used); 2) blood samples are periodically obtained via the tail vein from one mouse in each treatment group; and 3) the samples are analyzed for red and white blood cell

counts, blood cell composition, and the percent of lymphocytes versus polymorphonuclear cells. A comparison of results for each dosing regime with the controls indicates if toxicity is present.

[0452] At the termination of each toxicity study, further studies can be carried out by sacrificing the animals (preferably, in accordance with the American Veterinary Medical Association guidelines Report of the American Veterinary Medical Assoc. Panel on Euthanasia, *Journal of American Veterinary Medical Assoc.*, 202:229-249, 1993). Representative animals from each treatment group can then be examined by gross necropsy for immediate evidence of metastasis, unusual illness, or toxicity. Gross abnormalities in tissue are noted, and tissues are examined histologically. Compounds causing a reduction in body weight or blood components are less preferred, as are compounds having an adverse effect on major organs. In general, the greater the adverse effect the less preferred the compound.

[0453] For the treatment of cancers the expected daily dose of a hydrophobic pharmaceutical agent is between 1 to 500 mg/day, preferably 1 to 250 mg/day, and most preferably 1 to 50 mg/day. Drugs can be delivered less frequently provided plasma levels of the active moiety are sufficient to maintain therapeutic effectiveness.

[0454] Plasma levels should reflect the potency of the drug. Generally, the more potent the compound the lower the plasma levels necessary to achieve efficacy.

EXAMPLES

[0455] The examples below are not limiting and are merely representative of various aspects and features of the present invention. The examples below demonstrate the isolation and characterization of the STE20-related kinases of the invention.

EXAMPLE 1: Isolation of cDNAs Encoding Mammalian STE20-related Protein Kinases

Materials and Methods

Identification of novel clones

[0456] Total RNAs were isolated using the Guanidine Salts/Phenol extraction protocol of Chomczynski and Sacchi (P. Chomczynski and N. Sacchi, *Anal. Biochem.* 162, 156 (1987)) from primary human tumors, normal and tumor cell lines, normal human

tissues, and sorted human hematopoietic cells. These RNAs were used to generate single-stranded cDNA using the Superscript Preamplification System (GIBCO BRL, Gaithersburg, MD; Gerard, GF *et al.* (1989), FOCUS 11, 66) under conditions recommended by the manufacturer. A typical reaction used 10 µg total RNA with 1.5 µg oligo(dT)₁₂₋₁₈ in a reaction volume of 60 µL. The product was treated with RNaseH and diluted to 100 µL with H₂O. For subsequent PCR amplification, 1-4 µL of this sscDNA was used in each reaction.

[0457] Degenerate oligonucleotides were synthesized on an Applied Biosystems 3948 DNA synthesizer using established phosphoramidite chemistry, precipitated with ethanol and used unpurified for PCR. The sequence of some of the degenerate oligonucleotide primers and the amino acid motif they encode is as follows:

TRK1 5'-CTGAATTCGGNGCNTTYGGNAARGT-3'(SEQ ID NO:32)
GAFGKV (sense)(SEQ ID NO:37)

TRK4 5'-GCTGGATCCYTCNGGNGGCATCCA-3'(SEQ ID NO:33)
WMPPE (antisense)(SEQ ID NO:38)

ROS1 5'-GCNTTYGGNGARGTNTAYGARGG-3'(SEQ ID NO:34)
AFGEVYEG (sense)(SEQ ID NO:39)

CCK4b 5'-GCTGGATCCYTCNGGNSWCATCCA-3'(SEQ ID NO:35)
WMSPE (antisense)(SEQ ID NO:40)

CCK4c 5'-GAGTTYGGNGARGTNTTYTNGC-3'(SEQ ID NO:36)
EFGEVYEG (sense)(SEQ ID NO:41)

[0458] These primers were derived from the sense and antisense strands of conserved motifs within the catalytic domain of several protein kinases. Degenerate nucleotide residue designations are: N = A, C, G, or T; R = A or G; Y = C or T; H = A, C or T not G; D = A, G or T not C; S = C or G; and W = A or T.

[0459] PCR reactions were performed using degenerate primers applied to multiple single-stranded cDNAs. The primers were added at a final concentration of 5 µM each to a mixture containing 10 mM TrisHCl, pH 8.3, 50 mM KCl, 1.5 mM MgCl₂, 200 µM each deoxynucleoside triphosphate, 0.001% gelatin, 1.5 U AmpliTaq DNA Polymerase (Perkin-

Elmer/Cetus), and 1-4 μ L cDNA. Following 3 min denaturation at 95 °C, the cycling conditions were 94 °C for 30 s, 50 °C for 1 min, and 72 °C for 1 min 45 s for 35 cycles. PCR fragments migrating between 300-350 bp were isolated from 2% agarose gels using the GeneClean Kit (Bio101), and T-A cloned into the pCRII vector (Invitrogen Corp. U.S.A.) according to the manufacturer's protocol.

[0460] Colonies were selected for mini plasmid DNA-preparations using Qiagen columns and the plasmid DNA was sequenced using a cycle sequencing dye-terminator kit with AmpliTaq DNA Polymerase, FS (ABI, Foster City, CA). Sequencing reaction products were run on an ABI Prism 377 DNA Sequencer, and analyzed using the BLAST alignment algorithm (Altschul, S.F. *et al.*, J.Mol.Biol. 215: 403-10).

[0461] Additional PCR strategies were employed to connect various PCR fragments or ESTs using exact or near exact oligonucleotide primers as detailed in the results section for each cDNA. PCR conditions were as described above except the annealing temperatures were calculated for each oligo pair using the formula: $T_m = 4(G+C)+2(A+T)$.

Isolation of cDNA clones:

[0462] Human cDNA libraries were probed with PCR or EST fragments corresponding to STE20-related genes. Probes were 32 P-labeled by random priming and used at 2×10^6 cpm/mL following standard techniques for library screening. Pre-hybridization (3 h) and hybridization (overnight) were conducted at 42 °C in 5X SSC, 5X Denhart's solution, 2.5% dextran sulfate, 50 mM $\text{Na}_2\text{PO}_4/\text{NaHPO}_4$, pH 7.0, 50% formamide with 100 mg/mL denatured salmon sperm DNA. Stringent washes were performed at 65 °C in 0.1X SSC and 0.1% SDS. DNA sequencing was carried out on both strands using a cycle sequencing dye-terminator kit with AmpliTaq DNA Polymerase, FS (ABI, Foster City, CA). Sequencing reaction products were run on an ABI Prism 377 DNA Sequencer.

Makegene Bioinformatics EST assembler

[0463] The EST reports were downloaded from National Institute for Biotechnology Information. After uncompressing the files, the program 'report2est' was

scripted to extract the following information: 1) EST names, 2) GenBank Accession numbers, 3) GenBank gi numbers, 4) Clone Id numbers, 5) the nucleotide sequences of the ESTs 6) the organism, 7) the library name, 8) the name of the lab, and 9) the institution. The output of 'report2est' is a file in FASTA format with all of the information listed above in the first line of each entry except the sequence, which is listed in the second line of each entry. The resulting file is formatted for BLAST using 'pressdb' (available as part of the ncbi tool kit).

[0464] To build a gene or part of a gene from ESTs, the program 'makegene' was developed. Input to this program is a query sequence and the organism/species for which a gene is to be built. An initial search of the formatted EST database described above is performed using BLAST (blastn). Any results that contain warnings, such as polyA tails or other repeat elements, are eliminated from future queries. The program 'blast_parse_reports' was developed to extract the FASTA header line from the search results and the output is then filtered to extract only FASTA header lines for the desired species.

[0465] The initial results, having been filtered for warnings and species, go into a loop in which searches against the database are repeated until no new ESTs are found. The loop consists of the following steps: 1) when possible the names of both ends of the ESTs are extracted from the database by searching using the 'Clone Id' field or the part of the 'EST name' field before the .r or .s postscript, 2) any ESTs that have been used as queries in previous loops are removed from the current query by the program 'subtract', 3) the resulting list of ESTs is used to extract the sequences from the database by the program batch_parse_fasta, 4) BLAST is run against the database using each sequence, 5) the output files from BLAST containing warnings are removed, 6) the results are filtered by species, and 7) the loop is reentered if there were new ESTs found in the previous pass through the loop.

[0466] The ESTs chosen by 'makegene' are used as input for the program 'mpd2_cluster' (Hide, W., Burke, J, and Davison, D. U. of Houston, unpublished) which clusters overlapping sequences. The programs 'contig' (Kerlavage, T., TIGR, unpublished), 'gde2mult' and 'gde2sing' (Smith, S.W., *et al.*, CABIOS 10, 671-675 (1994)), are used to make an alignment and consensus sequence of the overlapping ESTs.

RESULTS

cDNA cloning and characterization of STLK2

[0467] The human STLK2 cDNA sequence is composed of two overlapping EST fragments, AA191319 and W16504, that were identified using a Smith-Waterman search of the EST database with STLK1 (MST3 GB:AF024636) as a query. The complete sequence of both clones was determined and used to generate the full-length human STLK2 sequence.

[0468] EST clone AA191319 contains a 1327 bp insert and an ORF of 1146 bp (382 amino acids). EST clone W16504 contains a 2474 bp insert (not including the poly-A tail) and an ORF of 687 bp (382 amino acids).

[0469] The full-length human STLK2 cDNA (SEQ ID NO. 1) is 3268 bp long. AA191319 spans positions 1-1327 and W16504 positions 743-3216. The overlap between these two clones exhibits 100% sequence identity. The human STLK2 cDNA contains a 1248 bp ORF flanked by a 181 bp 5' UTR (1-181) and a 1784 bp 3' UTR (1433-3216) that is followed by a 52 nucleotide polyadenylated region. A polyadenylation signal (AATAAA) is found at positions 3193-3198. The sequence flanking the first ATG conforms to the Kozak consensus for an initiating methionine, and is believed to be the translational start site for STLK2. Furthermore, human STLK2, and the related SOK-1 and MST3 proteins, conserve the amino acid sequence immediately following this presumed initiating methionine.

[0470] Several EST fragments span the complete STLK2 sequence with AA191319 at the 5' end and W16504 at the 3' end.

[0471] All searches against the public nucleic acid database (NRN) and protein database (NRP) were conducted using the Smith-Waterman gap alignment program ((Smith, TF and Waterman, MS (1981) J. Mol. Biol, 147, 195-197).) with the PAM100 matrix and gap open and extension penalties of 14:1, respectively.

cDNA Cloning and Characterization of STLK3

[0472] A mammalian STLK3 clone, 135-31-19, was first identified from a PCR screen with the degenerate oligos, TRK1 and TRK4, applied to a ssDNA generated from

adult rat brain substantia nigra. Sequence analysis of the 457 bp insert indicated that it represented a novel member of the STE20-subfamily of STKs.

[0473] A Smith-Waterman search of the EST database with the rat STLK3 fragment and human STLK1 (MST3 GB:AF024636) as queries identified several overlapping ESTs spanning most of the human STLK3 cDNA sequence. A Makegene analysis generated a 3037 bp contig from approximately 44 EST sequences. Since the 3' ESTs were not commercially available, a pair of primers (5'-CACAGAAACGGTCAGATTCAC-3'(SEQ ID NO: 42) and 5'-GATCAGGGTGACATCAAGGGAC-3'(SEQ ID NO: 43)) were derived from this region to generate PCR clone 3R21-20-6 from human fetal liver sscDNA. This clone and EST AA278967 were fully sequenced to generate the full-length STLK2 cDNA sequence.

[0474] AA278967 is a 837 bp EST isolated by the IMAGE consortium from cDNA made from CD20+/IgD- germinal center B cells sorted from human tonsillar cells.

[0475] PCR clone 3R21-20-6 was isolated from human fetal sscDNA and contains a 1116 bp insert, including a 1086 bp ORF encoding the 362 C-terminal amino acids of STLK3.

[0476] The full-length human STLK3 cDNA (SEQ ID NO. 2) is 3030 bp long. AA278967 spans positions 1-814 and 3R21-20-6 spans positions 464-1579. The overlap between these two clones exhibits 100% sequence identity. The remaining 1452 bp of 3' UTR is derived from an assembly of multiple unconfirmed EST fragments.

[0477] The near full-length human STLK3 cDNA (SEQ ID NO.2) is 3030 bp long and consists of a 1548 bp ORF flanked by a 1476 bp 3' UTR (1550-3025) and a 5 nucleotide polyadenylated region. A polyadenylation signal (AATAAA) begins at position 3004. Since the coding region is open throughout the 5' extent of this sequence, this is apparently a partial cDNA clone lacking the N-terminal start methionine. Six copies of a "GGCCCC" repeat were observed in positions 21-67. Five independent ESTs (AA150838, AA286879, AA251679, AA252004, AA278967) showed the same repeat, suggesting that this sequence may be an integral region of the human STLK3 gene. Stronger evidence for this being the case is provided by the sequence of the murine orthologue of STLK3 represented by a 876 bp EST W20737.

[0478] Multiple EST fragments span the complete STLK3 sequence with

AA278967 at the 5' end and AA628477 and others at the 3' end.

cDNA Cloning and Characterization of STLK4

[0479] The human STLK4 cDNA sequence is composed of two overlapping EST fragments, AA297759 and AA100484, that were identified using a Smith-Waterman search of the EST database with STLK1 (MST3 GB:AF024636) as a query. The complete sequence of both clones was determined and used to generate the near full-length human STLK4 sequence.

[0480] AA100484 is an IMAGE consortium cDNA clone isolated from the T-84 colonic epithelium cell line. It has an insert of 3694 bp and a coding region of 1146 bp (382 amino acids). A Smith-Waterman sequence alignment against the NR database showed this EST to be 71.4% identical to the human STE20-like kinase (GB:X99325).

[0481] W16504 is an IMAGE consortium clone isolated from a human fetal heart cDNA library. It has an insert length of 2474 bp (not including the poly-A tail) and a coding region of 687 bp (229 amino acids). A Smith-Waterman sequence alignment of W16504 against the NR database showed this EST to be 69.2% identical to the human STE20-like kinase (GB:X99325).

[0482] The full-length human STLK2 cDNA (SEQ ID NO. 1) is 3268 bp long. AA191319 spans positions 1-1327, and W16504 positions 743-3216. The overlap between these two clones is 585 bp long with 100% sequence identity.

[0483] AA100484 is an IMAGE consortium cDNA clone isolated from the T-84 colonic epithelium cell line. AA100484 covers the bulk of Human STLK4 with its 3694 bp, which spans positions 146-3839 of SEQ ID NO:3. A second EST, AA297759, isolated from a Jurkat T cell cDNA library, spans positions 1-271 of the human STLK4 contig. The two ESTs overlap over a 126 bp stretch that has only one nucleotide discrepancy at position 149 (G in AA297759 and T in AA100484). A T at this position was chosen for the SEQ ID NO:3 based on sequence data generated from A100484. The 5' 145 bp of human STLK4 contains three sequencing ambiguities (N's in SEQ ID NO:3) arising from sequence errors in the GenBank entry for AA297759. Three amino acid sequence ambiguities in the N-terminus of human STLK4 are present also in SEQ ID NO:7 as a consequence of the sequence inaccuracies from the EST entry.

[0484] The coding region of human STLK4 is 1242 bp long (2-1243), capable of encoding a 414 amino acid polypeptide, and is followed by a 2596 nucleotide 3' UTR (1244-3839). Human STLK4 ends in a polyadenylated stretch that has 18 adenines (3840-3857). A polyadenylation signal (AATAAA) is found between positions 3822-3827. Targeted-PCR cloning identified one rat orthologue of human STLK4, clone 135-31-19. In addition, one murine orthologue of human STLK4 was recognized in the EST database as AA117483. None of these orthologues add additional N-terminal sequence to the human STLK4.

[0485] The near full-length human STLK4 cDNA (SEQ ID NO.3) is 3857 bp long and consists of a 1242 bp ORF flanked by a 2596 bp 3' UTR (1244-3839) and an 18 nucleotide polyadenylated region. Polyadenylation signals (AATAAA) begin at positions 2181 and 3822. Since the coding region is open throughout the 5' extent of this sequence, this is apparently a partial cDNA clone lacking the N-terminal start methionine. A near full-length murine STLK4 cDNA is represented in the 1773 bp EST AA117438. It extends an additional 21 nucleotides 5' of the human STLK4 consensus, but since its coding region is open throughout the 5' extent of the sequence, this is also probably a partial cDNA clone lacking the N-terminal start methionine.

[0486] Several EST fragments span the complete STLK3 sequence with AA297759 at the 5' end and AA100484 and others at the 3' end.

cDNA Cloning and Characterization of STLK5

[0487] The human STLK5 cDNA sequence is composed of four overlapping sequences, AI418298, 2R96-13-1, 3R25-45-3 and R46685. A human STLK5 clone, F07734, was first identified using a Smith-Waterman search of the EST database with SPS_sc (U33057) as a query.

[0488] AI418298 is an IMAGE consortium cDNA clone with an 895 bp insert.

[0489] PCR clone 2R96-13-1 was isolated from human brain sscDNA using primers 5'-CTCATCTGTACACACTTCATGG(SEQ ID NO:44) and 5'-GATTCCCACACTGTAGATGTC(SEQ ID NO:45) derived from F07734. 2R96-13-1 contains a 330 bp insert and an ORF of 330 bp (110 amino acids).

[0490] EST clone R46685 was identified using a Smith-Waterman search of the

EST database with the C-terminus of SPS_sc (GB:U33057) as query. Sequence analysis of the 1047 bp insert identified this EST to contain an ORF of 285 bp (95 amino acids) encoding the C-terminus of human STLK5.

[0491] PCR clone 3R25-45-3 was isolated from human fetal brain sscDNA using primers 5'-GGCCCTCGACTACATCCACCACAT(SEQ ID NO:46) and 5'-CAACGAAACTAACACAGCATAAGG(SEQ ID NO:47) derived from 2R96-13-1 and R46685, respectively. 3R25-45-3 contains a 330 bp insert and an ORF of 750 bp (250 amino acids).

[0492] The full-length human STLK5 cDNA (SEQ ID NO:96) is 2110 bp long and consists of a 1119 bp ORF flanked by a 229 bp 5' UTR and a 762 bp 3' UTR. The sequence flanking the first ATG conforms to the Kozak consensus (*supra*) for an initiating methionine, and is believed to be the translational start site for STLK5.

[0493] Several EST fragments span the complete STLK5 sequence with AA297059 and F07734 at the 5' end and R46686 and F03423 and others at the 3' end.

[0494] STLK5 displays a 100% match over a 41 bp stretch (position 2-42, SEQ ID NO. 97) to a human CpG island repeat (Z61277).

cDNA Cloning and Characterization of STLK6

[0495] Human STLK6 was first identified in the translated EST database (AA219667) as a novel serine threonine kinase.

[0496] The partial human STLK6 cDNA (SEQ ID NO:98) is 2,001 bp long and consists of a 1,254 bp ORF flanked by a 75 bp 5' UTR and a 673 bp 3' UTR. The sequence flanking the first ATG conforms to the Kozak consensus (Kozak, M., Nucleic Acids Res. 15, 8125-8148 (1987)) for an initiating methionine, and is believed to be the translational start site for STLK6.

[0497] At the time of filing, inventors believe that STLK6 does not have any significant match in the nucleic acid database.

cDNA Cloning and Characterization of STLK7

[0498] Human STLK7 was first identified in the translated EST database (AA988954) as a novel serine threonine kinase. The original clone was not available

through public sources, so a PCR fragment amplified from the sequence of AA988954 yielded 5R54-21-2.

[0499] The partial human STLK7 cDNA (SEQ ID NO:100) is 311 bp long and consists of a 309 bp ORF. Since the coding region is open throughout the 5' and 3' extent of this sequence, this appears to be a partial cDNA clone lacking the N-terminal start methionine and C-terminal stop codon.

[0500] STLK7 shares 80% sequence identity to human SPAK (AF099989) over a 167 bp region and 50% nucleotide sequence identity to SLTK7 (SEQ ID NO. 101) over 391 nucleotides.

cDNA Cloning and Characterization of ZC1

[0501] The human ZC1 cDNA sequence is composed of two overlapping PCR clones, 3R25-24-2 and R65-12-2.

[0502] A human ZC1 clone, 125-33-5, was first identified from a PCR screen with degenerate oligos, TRK1 and TRK4, applied to sscDNA generated from human small airway epithelial cells (Clontech). Sequence analysis of the 503 bp insert identified a 501 bp ORF (167 amino acids) with the potential to encode a novel human STK related to the *C. elegans* ZC504.4 gene product.

[0503] PCR clone 3R25-24-2 was isolated from human SNB19 glioblastoma sscDNA using primers 5'-ATGGCGAACGACTCTCCCGCGAA(SEQ ID NO:48) and 5'-ACACCAAATCAACAAGTTTCACCTC(SEQ ID NO:49) derived from the N-terminus of a murine orthologue of ZC1 (NIK, GB:U88984) and the original human ZC1 clone 125-33-5, respectively. 3R25-24-2 contains a 527 bp insert and an ORF of 519 bp (173 amino acids).

[0504] PCR clone R65-12-2 was isolated as follows: A Smith-Waterman search of the EST database with the *C. elegans* ZC504.4 gene (GB:Z50029) as a query identified a human EST (W81656) whose ORF is related to the *C. elegans* gene and terminates in an identical residue (Trp). A primer was designed 3' to this stop codon (5'-AGTTACAAGGAATTCCAAGTTCT(SEQ ID NO:50)) and used in a PCR reaction with a primer derived from the original human ZC1 clone 125-33-5 (5'-ATGAAGAGGAAGAAATCAAACCTG(SEQ ID NO:51)) using sscDNA from human

SNB19 glioblastoma as a template. PCR clone R65-12-2 was identified and was found to contain a 3611 bp insert with a 3534 bp ORF encoding the C-terminal portion of human ZC1 (1178 amino acids).

[0505] The full-length human ZC1 cDNA (SEQ ID NO. 9) is 3798 bp long. Clone 3R25-24-2 spans positions 1-527, and clone R65-12-2 spans positions 188-3798. The overlap between these two clones exhibits 100% sequence identity. The human ZC1 contains a 3717 bp ORF (17-3723) flanked by a 6 bp 5' UTR and a 75 bp (3724-3798) 3' UTR. No polyadenylation signal (AATAAA) or polyadenylated region are present in the 3'UTR. The sequence flanking the first ATG conforms to the Kozak consensus for an initiating methionine, and is believed to be the translational start site for human ZC1.

[0506] Multiple EST fragments (W81656) match the 3' end of the human ZC1 gene, but at the time of filing, the inventors believe that none exist in GenBank or the EST database that match its 5' end.

cDNA Cloning and Characterization of ZC2

[0507] The human ZC2 cDNA sequence is composed of four overlapping PCR clones, G75-31-17, R65-24-6, 2R28-8-1, and R99-6-10.

[0508] A human ZC2 clone, G75-31-17, was first identified from a PCR screen with degenerate oligos, ROS1 (5'-GCNTTYGGNGARGTNTAYGARGG(SEQ ID NO:34)) and CCK4b (5'-GCTGGATCCYTCNGGNSWCATCCA(SEQ ID NO:35)), applied to sscDNA generated from the human HLT383 primary non-small cell lung cancer tissue. Sequence analysis of the 492 bp insert identified a 492 ORF (164 amino acids) with the potential to encode a novel human STK related to the *C. elegans* ZC504.4 gene product.

[0509] PCR clone R99-6-10 was isolated as follows: A Smith-Waterman search of the EST database with *C. elegans* ZC504.4 gene (GB:Z50029) as a query identified two overlapping human EST fragments (AA115844 and R51245) whose ORFs were related to the *C. elegans* gene and terminate in an identical residue (Trp). A primer was designed 3' to the stop codon found in R51245 (5'-AGATGGACTGTACTGGGAGG(SEQ ID NO:52)) and used in a PCR reaction with a primer derived from AA115844 (5'-ACTTTGTGCAGCTCTGTGGG(SEQ ID NO:53)) using human fetal brain sscDNA as a

template. PCR clone R99-6-10 was identified and was found to contain a 1095 bp insert with a 930 bp ORF encoding the C-terminal portion of human ZC2 (310 amino acids).

[0510] PCR clone R65-24-6 was isolated from human HT29 colon cancer cell line sscDNA using primers 5'-AAGGTTATGGATGTCACAGGG(SEQ ID NO:54) and 5'-AGATGGACTGTACTGGGAGG(SEQ ID NO:52) derived from G75-31-17 and R51245, respectively. The 3' primer used in this PCR reaction misprimed between positions 1634-1653 of this gene leading to the formation of a truncated product. R65-24-6 contains a 1593 bp insert and an ORF of 1593 bp (531 amino acids).

[0511] PCR clone 2R28-8-1 was isolated from human colon cancer cell line HT29 sscDNA using primers 5'-CTCACAAGGTTGCCAACAGG(SEQ ID NO:55) and 5'-AGTCCCCACCAGAAGGTTTAC(SEQ ID NO:56) derived from R65-24-6 and R99-6-10, respectively. 2R28-8-1 contains a 1538 bp insert and an ORF of 1536 bp (512 amino acids).

[0512] The partial human ZC2 cDNA (SEQ ID NO. 10) is 4055 bp long. Clone G75-31-17 spans positions 1-492, clone R65-24-6 spans positions 58-1650, clone 2R28-8-1 spans positions 1466-3003 and clone R99-6-10 spans positions 2961-4055. The overlapping regions between these clones exhibit 100% sequence identity except for a single guanine (G75-31-17) to adenosine (R65-24-6) mismatch at position 280 resulting in a Glu to Lys change. Based on the presence of an acidic residue in this position in human ZC1 and ZC3 and *C. elegans* ZC504.4, the sequence encoding the Glu is probably correct. The human ZC2 gene contains a 3891 bp ORF (1-3891) flanked by 164 bp (3892-4055) 3' UTR. No polyadenylation signal (AATAAA) or polyadenylated region is present in the 3'UTR.

[0513] Multiple EST fragments (R51245) match the 3' end of the human ZC2 gene, but at the time of filing, the inventors believe that none exist in GenBank or the EST database that match its 5' end.

cDNA Cloning and Characterization of ZC3

[0514] The human ZC3 cDNA sequence is composed of four overlapping PCR clones, G75-30-30, 3R33-5-3, 3R19-17-6, and R99-43-11.

[0515] A human ZC3 clone, G75-30-30, was first identified from a PCR screen

with degenerate oligos, ROS1 and CCK4b, applied to sscDNA generated from a human HLT370 primary non-small cell lung cancer tissue. Sequence analysis of the 492 bp insert identified a 492 ORF (164 amino acids) with the potential to encode a novel human STK related to the *C. elegans* ZC504.4 gene product.

[0516] PCR clone R99-43-11 was isolated as follows: A Smith-Waterman search of the EST database with the *C. elegans* ZC504.4 gene (GB:Z50029) as a query identified a human EST (R54563) whose ORF is related to the *C. elegans* gene and terminates in an identical residue (Trp). A primer was designed 3' to the stop codon found in R54563 (5'-TCAGGGGTCAGAGGTCACG(SEQ ID NO:57)) and used in a PCR reaction with a primer derived from the 5' end of R54563 (5'-CCCAAACCCTACCACAAATTC(SEQ ID NO:58)) using sscDNA from human fetal brain as a template. PCR clone R99-43-11 was identified and was found to contain a 719 bp insert with a 564 bp ORF encoding the C-terminal portion of human ZC3 (188 amino acids).

[0517] PCR clone 3R19-17-6 was isolated from human A549 lung cancer cell line sscDNA using primers 5'-CCCCCGGGAAACGATGACCA and 5'-AGCCGCTGCCCTCCTCTACTGT derived from G75-30-30 and R99-43-11, respectively. The 3' primer used in this PCR reaction misprimed leading to the formation of a truncated product. 3R19-17-6 contains a 1172 bp insert and an ORF of 1170 bp (390 amino acids).

[0518] PCR clone 3R33-5-3 was isolated from human A549 lung cancer cell line sscDNA using primers 5'-ACCGCAACATCGCCACCTACTAC(SEQ ID NO:61) and 5'-CTCGACGTCGTGGACCACC(SEQ ID NO:62) derived from G75-30-30 and 3R19-17-6, respectively. 3R33-5-3 contains a 2465 bp insert and an ORF of 2463 bp (821 amino acids).

[0519] The full-length human ZC3 cDNA (SEQ ID NO. 11) is 4133 bp long. Clone G75-30-30 spans positions 1-483, clone 3R33-5-3 spans positions 134-2598, clone 3R19-17-6 spans positions 2356-3512 and clone R99-43-11 spans positions 3415-4133. The overlaps between these clones exhibit 100% sequence identity. The human ZC3 gene contains a 3978 bp ORF (1-3978) flanked by a 152 bp 3' UTR (3979-4133). No polyadenylation signal (AATAAA) or polyadenylated region is present in the 3'UTR.

[0520] Multiple EST fragments (R54563) match the 3' end of the human ZC3 gene,

but at the time of filing, the inventors believe that none exist in GenBank or the EST database that match its 5' end.

cDNA Cloning and Characterization of ZC4

[0521] The human ZC4 cDNA sequence, represented by PCR fragment 3R25-27-1, was first identified in the human genomic cosmid 82J11 (GB:Z833850) containing exon sequences that displayed strong homology to the ZC504.4 *C. elegans* gene.

[0522] PCR clone 3R25-27-1 was isolated from human fetal liver sscDNA and primers 5'-CAATGTTAACCCACTCTATGTCTC(SEQ ID NO:63) and 5'-AGTTTGCCGATGTTTTCTTTTC(SEQ ID NO:64) derived from a potential ORF (positions 25729-25852) from the 82J11 cosmid and from an EST (R98571) encoding the C-terminus of the human ZC4 gene, respectively.

[0523] The partial human ZC4 cDNA (SEQ ID NO.12) is 1459 bp long and consists of a 1047 bp ORF (2-1048) flanked by a 411 bp (1049-1459) 3'UTR region. No polyadenylation signal (AATAAA) or polyadenylated region is present in the 3'UTR.

[0524] The N-terminal coding sequence for ZC4_h was extended by building a contiguous DNA sequence of 233,137 bp containing Z83850 and four other sequences: cU84B10 and cU230B10 (from the Sanger Human Genome Sequencing Project) and Z97356 and Z69734 (available from the National Institute for Biotechnology Information). The position of each sequence in the contig is represented in the table below.

Accession	Length	Start	End
cU84B10	43273	0	43273
Z97356	21848	43171	65018
Z69734	37077	63073	100149
cU230B10	11841	88416	100256
Z83850	132981	100156	233137

[0525] Sequences in ZC4 genomic contig.

[0526] The 233,137 bp contig was analyzed for exons using the programs FGENES 1.5 and FGENESH, human gene structure prediction software available from The Sanger Centre.

[0527] The resulting human ZC4 coding sequence (SEQ ID NO:104) is 3,681 bp

long (excluding the stop codon) and encodes for a STE20 kinase of 1227 amino acids.

cDNA Cloning and Characterization of KHS2

[0528] The human KHS2 cDNA sequence is composed of four overlapping clones, 3R25-51-2, 3R16-34-2, 3R16-31-2, and T79916.

[0529] A human KHS2 clone, AA250855, was first identified using a Smith-Waterman search of the EST database with KHS1 (GB:U77129) as a query. Sequence analysis of the 1112 bp insert identified a 618 bp ORF (206 amino acids) with the potential to encode a novel STK related to the human KHS1 gene product. Using AA250855 as a query, a second EST (AA446022) was found whose sequence was shown to contain the initiator methionine for human KHS2 based on a comparison with KHS1.

[0530] PCR clone 3R25-51-2 was isolated from human testicular cancer sscDNA using primers 5'-CCGCCATGAACCCCGGCTT(SEQ ID NO:65) and 5'-CGATTGCCAAAGACCGTGTCA(SEQ ID NO:66) derived from AA446022 and AA250855, respectively. 3R25-51-2 contains an 850 bp insert and an ORF of 849 bp (283 amino acids).

[0531] EST clone, T79916, was identified using a Smith-Waterman search of the EST database with the C-terminus of KHS1 (GB:U77129) as a query. Sequence analysis of the 2107 bp insert identified this EST to contain an ORF of 345 bp (115 amino acids disrupted by a single stop codon) encoding the C-terminus of human KHS2, followed by 1762 bp 3'UTR.

[0532] PCR clone 3R16-34-2 was isolated from human testis sscDNA using primers 5'-AGAAGTTGCAGCTGTTGAGAGGA(SEQ ID NO:67) and 5'-TATGGCCCGTGTAAGGATTTC(SEQ ID NO:68) derived from AA250885 and T79916, respectively. 3R16-34-2 contains an 1516 bp insert and an ORF of 1128 bp (376 amino acids).

[0533] PCR clone 3R16-31-2 was isolated from normal human colon sscDNA using primers 5'-GTGCCAGAAGTGTTGTGTTGTAA(SEQ ID NO:69) and 5'-TATGGCCCGTGTAAGGATTTC(SEQ ID NO:68) derived from EST T79916. 3R16-31-2 contains a 728 bp insert and an ORF of 669 bp (223 amino acids). This clone lacked the stop codon present within EST T79916 (position 2662 in the KHS2 sequence).

[0534] The full-length human KHS2 cDNA (SEQ ID NO.17) is 4023 bp long. Clone 3R25-51-2 spans positions 1-855, clone AA250885 spans positions 336-923, clone 3R16-34-2 spans positions 545-2061, and clone T79916 spans positions 1917-4023. The overlapping regions between these clones exhibit 100% sequence identity, except for 4 nucleotide differences, two of which are silent, a third corrects the internal stop codon at position 2662, and the fourth at position 247 (T to C change) results in a Pro to Leu change. The human KHS2 cDNA contains a 2682 bp ORF (6-2687) flanked by a 5 bp (1-5) 5'UTR and a 1336 bp (2688-4023) 3' UTR. A potential polyadenylation signal (AATAAA) is found at positions 4008-4013. No polyadenylated region is present in the 3'UTR. The sequence flanking the first ATG is in a poor context for translational initiation, however, a 134 bp 5'UTR sequence from EST AA446022 did not reveal any additional ATG's and displayed two in-frame stop codons 5' to the putative start ATG for human KHS2.

[0535] Multiple EST fragments match the 5' end (AA446022) as well as the 3' end (R37625) of the human KHS2 gene.

cDNA Cloning and Characterization of SULU1

[0536] The human SULU1 cDNA sequence is composed of three overlapping clones, N40091, 2R90-1-1 and R90907.

[0537] A human SULU1 clone, N40091, was first identified using a Smith-Waterman search of the EST database with the *C. elegans* SULU gene (GB: U32275) as a query. Sequence analysis of the 1321 bp insert identified a 906 bp ORF (302 amino acids) with the potential to encode a novel human STK related to the *C. elegans* SULU gene product.

[0538] EST clone R90907 was first identified using a Smith-Waterman search of the EST database with the 3' end of the *C. elegans* SULU gene (GB: U32275) as a query. Sequence analysis of the 1647 bp insert identified a 578 bp ORF (192 amino acids) with the potential to encode the C-terminus of the human SULU1 gene product.

[0539] PCR clone 2R90-1-1 was isolated from human HT29 colon cancer cell cDNA using primers 5'- TATTGAATTGGCGGAACGGAAG(SEQ ID NO:70) and 5'- TTGTTTTGTGCTCATTCTTTGGAG(SEQ ID NO:71) derived from N40091 and

R90907, respectively. 2R90-1-1 contains a 1625 bp insert and an ORF of 1623 bp (541 amino acids).

[0540] The full-length human SULU1 cDNA (SEQ ID NO.19) is 4177 bp long. Clone N40091 spans positions 1-1321, clone 2R90-1-1 spans positions 1048-2671, and clone R90907 spans positions 2531-4177. The overlapping regions between these clones exhibit 100% sequence identity. The human SULU1 cDNA contains a 2694 bp ORF (415-3108) flanked by a 414 bp (1-414) 5'UTR and a 1069 bp (3109-4177) 3' UTR followed by a 19 nucleotide polydenylated region. A potential polyadenylation signal (AATAAA) is found at positions 4164-4169. The sequence flanking the first ATG conforms to the Kozak consensus for an initiating methionine, and is believed to be the translational start site for human SULU1.

[0541] Multiple EST fragments match the 5' end (N27153) as well as the 3' end (R90908) of the human SULU1 gene.

cDNA Cloning and Characterization of Murine SULU3

[0542] The murine SULU3 cDNA sequence is represented by PCR fragment 2R92-1-6.

[0543] A murine SULU3 clone, G83-4-5, was first identified from a PCR screen with degenerate oligos, CCK4c and CCK4b, applied to sscDNA generated from murine day-12 embryos. Sequence analysis of the 473 bp insert identified a 471 ORF (157 amino acids) with the potential to encode a novel human STK related to the *C. elegans* SULU gene (GB: U32275) product. The antisense strand of G83-4-5 is identical at the nucleic acid level to the 5'UTR of the murine ets1 protooncogenic transcription factor (GB:X53953). This homology is likely the result of a cloning artifact attached to the 5' end of the database entry for murine ets1.

[0544] PCR clone 3R19-17-6 was isolated from human A549 cell sscDNA using primers 5'-CCCCCGGGAAACGATGACCA(SEQ ID NP:59) and 5'-AGCCGCTGCCCTCCTCTACTGT(SEQ ID NO:60) derived from G75-30-30 and R99-43-11, respectively. The 3' primer used in this PCR reaction misprimed leading to the formation of a truncated product. 3R19-17-6 contains a 1172 bp insert and an ORF of 1170 bp (390 amino acids).

[0545] PCR clone 2R92-1-6 was isolated from murine d8 embryo sscDNA using primers 5'-ACCGCAACATCGCCACCTACTAC(SEQ ID NO:61) and 5'-GATTGCTTTGTGCTCATTCTTTGG(SEQ ID NO:72) derived from the 5' UTR of the *ets1* gene and the human EST AA234623, respectively. The latter (shown herein) encodes the C-terminus of human SULU3. 2R92-1-6 contains a 2249 bp insert and an ORF of 2244 bp (748 amino acids).

[0546] The partial murine SULU3 cDNA (SEQ ID NO.21) is 2249 bp long and consists of a 2244 bp ORF (6-2249) flanked by a 5 bp (1-5) 5'UTR. The sequence flanking the first ATG conforms to the Kozak consensus for an initiating methionine, and is believed to be the translational start site for murine SULU3.

[0547] One EST fragment (AA446022) matches the 3' end of the partial murine SULU3 gene, but at the time of filing, the inventors believe that none exist in GenBank or the EST database that match its 5' end.

cDNA Cloning and Characterization of Human SULU3

[0548] The human SULU3 cDNA sequence is composed of two overlapping clones, 2R90-22-1 and AA234623.

[0549] A human SULU3 clone, AA234623, was first identified using a Smith-Waterman search of the EST database with the *C. elegans* SULU gene (GB: U32275) as a query. Sequence analysis of the 2652 bp insert identified a 1185 bp ORF (395 amino acids) with the potential to encode the C-terminus of a novel human STK related to the *C. elegans* SULU gene product.

[0550] PCR clone 2R90-22-1 was isolated from human SKMel128 melanoma cell line sscDNA using primers 5'- TATTGAATTGGCGGAACGGAAG(SEQ ID NO:70) and 5'- TTGTTCTAAGAGTGCCCTCCG(SEQ ID NO:73) derived from the murine SULU3 2R92-1-6 clone and from AA234623, respectively. 2R92-1-6 contains a 1897 bp insert and an ORF of 1896 bp (632 amino acids).

[0551] The partial human SULU3 cDNA (SEQ ID NO.20) is 3824 bp long. Clone 2R90-22-1 spans positions 1-1897 and clone AA234623 spans positions 1173. The overlapping region between these clones exhibits 100% sequence identity. The human SULU3 cDNA contains a 2358 bp ORF (2-2359) flanked by a 1465 bp (2360-3824)

3'UTR followed by a 19 nucleotide polydenylated region. A potential polyadenylation signal (AATAAA) is found at positions 2602-2607. Since the coding region is open throughout the 5' extent of this sequence, this is apparently a partial cDNA clone lacking the N-terminal start methionine.

[0552] Multiple EST fragments (R02283) match the 3' end of the human SULU3 gene, but at the time of filing, the inventors believe that none exist in GenBank or the EST database that match its 5' end.

cDNA Cloning and Characterization of GEK2

[0553] The human GEK2 cDNA sequence is composed of three overlapping clones, AA459448, 3R25-48-1 and GEK2_h#3.

[0554] A human GEK2 clone, AA459448, was first identified using a Smith-Waterman search of the EST database with the human SLK gene (GB: AB002804) as a query. Sequence analysis of the 1286 bp insert identified a 1227 bp ORF (409 amino acids) with the potential to encode the N-terminus of a novel human STK related to the human SLK gene product. An additional Smith-Waterman search using the C-terminus of the SLK gene as a query yielded three additional EST's, AA323687, AA380492 and AA168869, that encode the C-terminal region of human GEK2.

[0555] PCR clone 2R98-41-17 was isolated from human testis sscDNA using primers 5'- AAGACCATGCCGTGCGCCG (SEQ ID NO:74) and 5'- ATTCCTTCAGGTTCTGGTTATGG (SEQ ID NO:75) derived from AA323687 and from AA380492, respectively. 2R98-41-17 contains a 851 bp insert and an ORF of 849 bp (283 amino acids).

[0556] PCR clone GEK2_h#3 was isolated from human sscDNA made from the H23 tumor cell line using primers 5'- GCAGCAAGTGGAGAAGATGG (SEQ ID NO:109) and 5'- GGAAGCATCCCCAGAGCTGTAG (SEQ ID NO:110) derived from the sequence of clone 3R25-48-1 and from the 3' end of murine LOK (GB:D89728), respectively. GEK2_h#3 contains a 1042bp insert and an ORF of 1041 bp (347 amino acids).

[0557] The full-length human GEK2 cDNA (SEQ ID NO:106) is 2962 bp long. Clone AA459448 spans positions 1-1286, clone 3R25-48-1 spans positions 1100-2449 and clone GEK2_h#3 spans positions 1920-2962. The overlapping regions between these clones

exhibit 100% sequence identity.

[0558] The human GEK2 cDNA contains a 2904 bp ORF (59-2962) flanked by a 58 bp (1-58) 5'UTR. The sequence flanking the first ATG conforms to the Kozak consensus for an initiating methionine, and is believed to be the translational start site for human GEK2.

[0559] Multiple EST fragments (AA465671) match the 5' end of the sequence, but only one (AA380492) matches the 3' end of the human GEK2 gene.

cDNA Cloning and Characterization of PAK4

[0560] The human PAK4 cDNA sequence is represented by clone SNB2#1.

[0561] A human PAK4 clone, R88460, was first identified using a Smith-Waterman search of the EST database with the human PAK gene (GB: U24152) as a query. Sequence analysis of the 2332 bp insert identified a 930 bp ORF (310 amino acids) with the potential to encode the C-terminus of a novel human STK related to the human PAK gene product.

[0562] cDNA clone SNB2#1 was isolated from human glioblastoma cell line SNB75 cDNA library using a probe derived from R88460. SNB2#1 contains a 3604 bp insert and an ORF of 2043 bp (681 amino acids).

[0563] The full-length human PAK4 cDNA (SEQ ID NO.27) is 3604 bp long and consists of a 2043 bp ORF (143-2185) flanked by a 142 bp (1-142) 5'UTR and a 1419 3' UTR followed by a 22 nucleotide polydenylated region. A potential polyadenylation signal (AATTAAA) is found at positions 3582-3588. The sequence flanking the first ATG conforms to the Kozak consensus for an initiating methionine, and is believed to be the translational start site for human PAK4. The 3' UTR of the PAK4 gene contains a GT dinucleotide repeat prone to undergo expansion based on the number of repeats found in clones SNB#1 and R88460, 32 and 23, respectively. Several neurologic disorders have been correlated with the expansion of di- or tri-nucleotide repeats similar to those found in the PAK4 sequence, suggesting PAK 4 may also be a disease target and that this repeat in its 3'UTR may serve as a diagnostic marker.

[0564] Multiple EST fragments (AA535791) match the 3' end of the human PAK4 gene, but at the time of filing, the inventors believe that none exist in GenBank or the EST

database that match its 5' end.

cDNA Cloning and Characterization of PAK5

[0565] The full-length human PAK5 cDNA sequence is composed of two overlapping clones, H450#1-1 and SNB8#5.

[0566] A human PAK5 clone, R18825, was first identified using a Smith-Waterman search of the EST database with the human PAK4 gene as a query. Sequence analysis of the 1248 bp insert identified a 420 bp ORF (140 amino acids) with the potential to encode the C-terminus of a novel human STK related to the human PAK4 gene product.

[0567] cDNA clone SNB8#5 was isolated from human SNB75 cDNA library using a probe derived from R18825. SNB2#1 contains a 2028 bp insert and an ORF of 1194 bp (398 amino acids).

[0568] The partial human PAK5 cDNA (SEQ ID NO.28) is 2028 bp long and consists of a 1194 bp ORF (2-1195) flanked by an 833 bp (1196-2028) 3'UTR followed by a 22 nucleotide polydenylated region. A potential polyadenylation signal (AATTAAA) is found at positions 2004-2010. Since the coding region is open throughout the 5' extent of this sequence, this is apparently a partial cDNA clone lacking the N-terminal start methionine.

[0569] Clone H460#1-1 was isolated from a human lung H460 cDNA library using a probe derived from the partial SNB2#1 cDNA clone described above. Sequence analysis of the 2526 bp insert identified a 1773 bp ORF (592 amino acids) with the potential to encode a full-length PAK5.

[0570] The human PAK5 cDNA (SEQ ID NO:102) is 2,806 bp long and consists of a 1,773 bp ORF flanked by a 201 bp 5' UTR and a 833 bp 3' UTR. The sequence flanking the first ATG conforms to the Kozak consensus (Kozak, M., Nucleic Acids Res. 15, 8125-8148 (1987)) for an initiating methionine, and is believed to be the translational start site for PAK5.

[0571] PAK5 shares 99% sequence identity over 2795 bp to a recent database entry, AF005046. These sequences are presumed to be from the same gene, with minor polymorphic variations.

EXAMPLE 2: Expression Analysis of Mammalian STE20-related Protein Kinases

Materials and Methods

Northern blot analysis

[0572] Northern blots were prepared by running 10 µg total RNA isolated from 60 human tumor cell lines (HOP-92, EKVX, NCI-H23, NCI-H226, NCI-H322M, NCI-H460, NCI-H522, A549, HOP-62, OVCAR-3, OVCAR-4, OVCAR-5, OVCAR-8, IGROV1, SK-OV-3, SNB-19, SNB-75, U251, SF-268, SF-295, SF-539, CCRF-CEM, K-562, MOLT-4, HL-60, RPMI 8226, SR, DU-145, PC-3, HT-29, HCC-2998, HCT-116, SW620, Colo 205, HTC15, KM-12, UO-31, SN12C, A498, CaKi1, RXF-393, ACHN, 786-0, TK-10, LOX IMVI, Malme-3M, SK-MEL-2, SK-MEL-5, SK-MEL-28, UACC-62, UACC-257, M14, MCF-7, MCF-7/ADR RES, Hs578T, MDA-MB-231, MDA-MB-435, MDA-N, BT-549, T47D), from 22 human adult tissues (thymus, lung, duodenum, colon, testis, brain, cerebellum, cortex, salivary gland, liver, pancreas, kidney, spleen, stomach, uterus, prostate, skeletal muscle, placenta, mammary gland, bladder, lymph node, adipose tissue), and 2 human fetal normal tissues (fetal liver, fetal brain), on a denaturing formaldehyde 1.2% agarose gel and transferring to nylon membranes.

[0573] Filters were hybridized with random primed [$\alpha^{32}\text{P}$]dCTP-labeled probes synthesized from the inserts of several of the STE20-related kinase genes. Hybridization was performed at 42 °C overnight in 6X SSC, 0.1% SDS, 1X Denhardt's solution, 100 µg/mL denatured herring sperm DNA with $1-2 \times 10^6$ cpm/mL of ^{32}P -labeled DNA probes. The filters were washed in 0.1X SSC/0.1% SDS, 65 °C, and exposed on a Molecular Dynamics phosphorimager.

Quantitative PCR analysis

[0574] RNA was isolated from a variety of normal human tissues and cell lines. Single stranded cDNA was synthesized from 10 µg of each RNA as described above using the Superscript Preamplification System (GibcoBRL). These single strand templates were then used in a 25 cycle PCR reaction with primers specific to each clone. Reaction products were electrophoresed on 2% agarose gels, stained with ethidium bromide and photographed on a UV light box. The relative intensity of the STK-specific bands were estimated for each sample.

DNA Array Based Expression Analysis

[0575] Plasmid DNA array blots were prepared by loading 0.5 μ g denatured plasmid for each STE20-related kinase on a nylon membrane. The [α^{32} P]dCTP labeled single stranded DNA probes were synthesized from the total RNA isolated from several human immune tissue sources or tumor cells (thymus, dendrocytes, mast cells, monocytes, B cells (primary, Jurkat, RPMI8226, SR), T cells (CD8/CD4+, TH1, TH2, CEM, MOLT4), K562 (megakaryocytes). Hybridization was performed at 42 °C for 16 hours in 6X SSC, 0.1% SDS, 1X Denhardt's solution, 100 μ g/mL denatured herring sperm DNA with 10⁶ cpm/mL of [α^{32} P]dCTP labeled single stranded probe. The filters were washed in 0.1X SSC/0.1% SDS, 65 °C, and exposed for quantitative analysis on a Molecular Dynamics phosphorimager.

RESULTS

Distribution of STE20-Related Gene Transcripts in Normal Tissues and Tumor Cell Lines

[0576] ZC1, ZC2, and ZC3 RNA expression was analyzed by quantitative PCR from multiple human normal tissues, cultured primary epithelial and endothelial cells, and tumor cell lines. The results are summarized in Tables 1 and 2, with relative expression values ranging from 0 (undetectable) to 23 (very strong). An “x” refers to sample not tested. ZC1, ZC2, and ZC3 were all expressed at very low levels in most normal human tissues, however ZC1 and ZC2 were more abundant in cultured epithelial cells and ZC3 in normal kidney and breast tissue.

[0577] Expression of these 3 genes was also examined in a panel of human tumor cell lines representing a diverse sampling of tumor types (Table 2). ZC1 and ZC2 showed strong expression in cell lines from most melanomas and renal tumors and from some non-small cell lung cancers and colon tumors. ZC3 expression was consistently lower in the tumor cell lines except for high expression in most breast cancers and leukemias. The robust overexpression ZC1, ZC2, and ZC3 in tumor cells versus normal tissues may provide an attractive target for oncology drug development.

[0578] Expression of all the novel STE20-related kinases was examined in a panel of human immune tissues/cells by hybridization to a DNA array blot containing plasmids

encoding each of these genes. STLK2 was broadly expressed in all 14 immune samples, whereas STLK4 and PAK4 were highly expressed in a subset of 6-7 of the samples (Table 3). Several other kinases (SULU3, ZC4, KHS2) had more restricted expression, while others were expressed in only a single immune source (STLK3, thymus; ZC1, dendrocytes; ZC3, monocytes; PAK5, mast cells and MOLT4), and several more were absent from all the immune sources assayed (GEK2, SULU1, ZC2, STLK5). These expression patterns were quite distinct among members of the same subfamily (*i.e.*, ZC1, ZC2, ZC3 and ZC4, or PAK1, PAK2, PAK3, PAK4, PAK5). This analysis suggests that some of these kinases may be candidate targets for various immune disorders, and that some, which are more broadly expressed, may mediate functions vital to the basic biology of most proliferating cells.

TABLE 1

ZC1, ZC2 and ZC3 Expression
in Normal Human Tissues and Cells

Sample		ZC1	ZC2	ZC3
NORMAL				
Brain	Tiss	2.8	0.6	0.9
Duod	Tiss	3.8	1.5	0.3
Heart	Tiss	1.2	0.3	0.0
Kidney	Tiss	0.7	0.0	7.0
Lung	Tiss	1.6	0.2	0.0
Pancreas	Tiss	2.0	0.4	2.5
Placenta	Tiss	1.4	0.0	0.0
Sal gl.	Tiss	3.0	0.3	3.2
Sk mus.	Tiss	2.3	0.1	0.1
Spleen	Tiss	0.4	0.0	x
Stomach	Tiss	0.8	0.0	0.0
Thymus	Tiss	3.5	0.4	1.5
Cereb	Tiss	2.8	1.1	4.4

Liver	Tiss	1.8	0.0	0.4
Uterus	Tiss	1.6	0.0	1.4
Prostate	Tiss	1.4	0.0	1.6
Testis	Tiss	x	x	5.8
f Brain	Tiss	x	x	3.1
Mam gl	Tiss	x	x	7.2
HCAEC	ENDO	1.0	0.0	0.0
HMVEC-d	ENDO	0.7	0.0	0.4
HMVEC-L	ENDO	2.2	1.6	1.8
HPAEC	ENDO	9.3	5.3	6.4
HMEC	EPI	4.1	2.3	1.9
RPTEC	EPI	3.6	2.2	0.2
HRCE	EPI	5.3	3.5	1.3
HSAE	EPI	0.9	3.3	4.8

TABLE 2

ZC1, ZC2 and ZC3 Expression in Tumor Cell ILnes

Sample	Origin	ZC1	ZC2	ZC3
HOP-92	Lung	9.3	7.2	3.3
EKVX	Lung	10.7	3.7	3.5
NCI-H23	Lung	5.8	6.3	4.1
NCI-H226	Lung	6.5	6.8	3.3
NCI-H322M	Lung	3.5	5.8	4.9
NCI-H460	Lung	4.5	3.7	2.9
NCI-H522	Lung	4.7	3.3	4.6
A549/ATCC	Lung	3.8	3.6	4.1

Sample	Origin	ZC1	ZC2	ZC3
HCC-2998	Colon	2.4	3.8	3.0
HCT 116	Colon	2.2	2.1	5.4
SW-620	Colon	7.8	12.1	3.1
COLO 205	Colon	9.1	16.2	3.0
HCT-15	Colon	13.8	4.9	2.5
KM-12	Colon	7.0	13.2	3.1
UO-31	Colon	10.4	10.6	0.9
SN12C	Renal	8.1	3.4	2.8

HOP-62	Lung	4.3	3.8	4.2
OVCAR-3	Ovary	2.9	3.1	1.5
OVCAR-4	Ovary	3.3	1.0	3.8
OVCAR-5	Ovary	2.6	3.6	2.2
OVCAR-8	Ovary	3.6	2.0	4.7
IGROV1	Ovary	3.8	1.7	3.2
SK-OV-3	Ovary	4.9	0.0	3.5
SNB-19	CNS	5.1	5.4	4.2
SNB-75	CNS	2.5	0.9	0.7
U251	CNS	1.5	1.2	0.6
SF-268	CNS	5.8	2.7	3.0
SF-295	CNS	6.4	1.1	3.2
SF-539	CNS	5.1	2.9	4.3
CCRF-CEM	Leuk	3.4	2.7	3.1
K-562	Leuk	4.1	6.3	4.3
MOLT-4	Leuk	7.1	3.4	4.2
HL-60	Leuk	x	x	0.4
RPMI 8226	Leuk	0.5	0.2	1.4
SR	Leuk	3.5	7.2	5.4
DU-145	Pro	x	x	3.4
PC-3	Pro	x	x	3.4
HT-29	Colon	2.4	5.9	6.6

A498	Renal	6.2	3.1	2.9
Caki-1	Renal	9.2	14.4	2.3
RXF 393	Renal	10.6	4.8	2.8
ACHN	Renal	9.3	6.0	3.9
786-0	Renal	8.8	15.6	5.6
TK-10	Renal	20.9	21.2	5.0
LOX IMVI	Mel	2.3	2.4	3.3
Malme-3M	Mel	x	x	2.2
SK-MEL-2	Mel	15.7	14.1	2.9
SK-MEL-5	Mel	7.9	7.0	0.0
SK-MEL-28	Mel	16.5	23.1	0.0
UACC-62	Mel	12.1	18.3	5.3
UACC-257	Mel	10.8	9.4	6.2
M14	Mel	4.4	0.9	7.9
MCF7	Breast	4.8	1.3	7.7
MCF-7/ADR	Breast	8.8	3.4	7.7
Hs 578T	Breast	6.9	2.6	5.7
MDA-MB-231	Breast	5.7	1.9	6.4
MDA-MB-435	Breast	4.8	6.7	9.1
MDA-N	Breast	7.3	6.3	9.1
BT-549	Breast	3.6	1.9	8.0
T-47D	Breast	0.4	12.3	9.3

Table 3: STE20-related kinase expression in a human immune panel

KINASE	thymus	Dendro- cytes	Mast cells	Mono- cytes	B cells	CD8+ CD4+	TH1	TH2
GEK2	350	350	350	350	350	350	350	350
SULU1	350	350	350	350	350	350	350	350
SULU3	350	350	350	350	12149	350	5115	350
STLK2	117770	13771	27620	92036	18305	39109	5408	3564
STLK3	8624	350	350	350	350	350	350	350
STLK4	8524	350	350	350	350	8685	5642	350
STLK5	xxx	xxx	xxx	xxx	350	350	350	xxx
ZC1	350	3377	350	350	350	350	350	350
ZC2	350	350	350	350	350	350	350	350
ZC3	350	350	350	20156	350	350	350	350
ZC4	xxx	xxx	xxx	xxx	350	350	350	xxx
KHS2	8766	2508	350	56575	350	350	350	350
PAK4	32658	7684	3729	100948	350	350	350	1604
PAK5	350	350	4905	350	350	350	350	350

KINASE	CEM (T cell)	MOLT4 (T cell)	JURKAT (B cell)	RPMI8226 (B cell)	SR (B cell)	K562 (MO)
GEK2	350	350	350	350	350	350
SULU1	350	350	350	350	350	350
SULU3	350	350	350	350	350	350
STLK2	47236	53262	47605	22560	65936	30390
STLK3	350	350	350	350	350	350
STLK4	3648	350	26772	1570	350	350
STLK5	350	350	350	xxx	350	350
ZC1	350	350	350	350	350	350

ZC2	350	350	350	350	350	350
ZC3	350	350	350	350	350	350
ZC4	1094	7813	14945	xxx	350	6385
KHS2	350	350	350	350	350	350
PAK4	350	10246	350	3229	350	350
PAK5	350	12672	350	350	350	350

Transcript size from Northern data

Kinase	(kb)
STLK2	3.8
STLK4	5.0
ZC1	6.9/4.7
ZC2	6.0/8.0
ZC4	5
KHS2	4.4
SULU1	4.5
SULU3	10.0
GEK2	5.5
PAK4	4.8
PAK5	3.5

[0579] STLK2 is widely expressed; the highest expression levels were found in placenta, spleen and PBL.

[0580] STLK4 is also widely expressed in normal tissues including heart, brain, placenta, lung, liver, skeletal muscle, kidney, pancreas, spleen, thymus, prostate, testis, ovary, small intestine, colon, and peripheral blood lymphocytes. STLK4 was also detected in Jurkat T cells.

[0581] ZC1 is highly overexpressed in the following human cancer cell lines: HOP-92, EKVX, NCI-H23, NCI-H226, NCI-H322M, NCI-H522, A549, HOP-62 (lung); OVCAR-3, OVCAR-4, OVCAR-5 (ovary); SNB-19, U251, SF-268, SF-295, SF-539 (CNS); K-562, RPMI-8226 (leukemia); DU-145, PC-3 (prostate); HT-29, HCC-2998, HCT-116, SW620, COLO-205, HCT-15, KM-12 (colon); UO-31, CAKi-1, RXF-393, 786-0, TK-10 (renal); LOXIMVI, Malme-3M, SK-MEL-2, SK-MEL-28, UACC-62, UACC-257, M14 (melanoma); and MCF-7, MCF-7/ADR, HIS 578T, MDA-MB-231, MDA-MB-431, MDA-N, BT-549, T-47D (breast).

[0582] ZC2 is expressed in brain and testis. It is highly overexpressed in the following human cancer cell lines: TK-10 (renal); SK-MEL-28, UACC-62 (melanoma); T47D (breast).

[0583] Moderate expression in HOP92 (lung); OVCAR4, IGROV1 (ovary); DNB75, U251 (brain); K-562 (leukemia); and COLO205 (colon).

[0584] SULU1 is overexpressed in the following human cancer cell lines: HOP-92, EKVX, NCI-H23, NCI-H226, NCI-H322M, NCI-H522, A549, HOP-62 (lung); OVCAR-3, OVCAR-4, OVCAR-5, SK-OV-3 (ovary); SNB-19, U251, SF-268, SF-295, SF-539 (CNS); K-562, RPMI-8226 (leukemia); DU-145, PC-3 (prostate); HT-29, HCC-2998, HCT-116, SW620, COLO-205, HCT-15, KM-12 (colon); UO-31, CAKi-1, RXF-393, 786-0, TK-10 (renal); LOX, IMVI, Malme-3M, SK-MEL-2, SK-MEL-28, UACC-62, UACC-257, M14 (melanoma); MCF-7, MCF-7/ADR, HIS 578T, MDA-MB-231, MDA-MB-431, MDA-N, BT-549, T-47D (breast)

[0585] SULU3 showed a broad pattern of expression in the normal tissue panel of RNAs.

[0586] GEK2 was expressed in spleen, thymus and testis. Expression was high in the cell lines RBL-2H3 and H441.

[0587] PAK4 was expressed in the normal tissues: brain, testis and prostate, and in the human cancer cell lines: HNCI-H23 (lung); OVCAR-3 (ovary); SNB-19, U251 (CNS); RPMI-8226 (leukemia); DU-145 (prostate); COLO-205, HCT-15 (colon).

[0588] PAK5 showed weak expression levels in the normal tissues: brain, testes, bladder, colon, adrenal medulla, spleen, fetal liver, breast, cerebral cortex, cerebellum, thymus, salivary gland, lung, stomach, duodenum, uterus, prostate, skeletal muscle and placenta. PAK5 was overexpressed in the human cancer cell lines: HOP-92, EKVX, NCI-H23, NCI-H226, NCI-H322M, NCI-H522, A549, HOP-62 (lung); OVCAR-3, OVCAR-4, OVCAR-5, SK-OV-3 (ovary); SNB-19, U251, SF-268, SF-295, SF-539 (CNS); K-562, RPMI-8226 (leukemia); DU-145, PC-3 (prostate); HT-29, HCC-2998, HCT-116, SW620, COLO-205, HCT-15, KM-12 (colon); UO-31, CAKi-1, RXF-393, 786-0, TK-10 (renal); LOXIMVI, Malme-3M, SK-MEL-2, SK-MEL-28, UACC-62, UACC-257, M14 (melanoma); MCF-7, MCF-7/ADR, HIS 578T, MDA-MB-231, MDA-MB-431, MDA-N, BT-549, T-47D (breast).

EXAMPLE 3: STE20-related Protein Kinase Gene Expression Vector Construction

Materials and Methods

Expression Vector Construction

[0589] Several expression constructs were generated for some of the human STE20-related cDNAs including: a) full-length clones in a pCDNA expression vector; b) a GST-fusion construct containing the catalytic domain of the novel STE20-related kinase fused to the C-terminal end of a GST expression cassette; and c) a full-length clone containing a Lys to Ala (K to A) mutation at the predicted ATP binding site within the kinase domain, inserted in the pCDNA vector.

[0590] The “K to A” mutants of the STE20-related kinase might function as dominant negative constructs, and will be used to elucidate the function of these novel STKs.

RESULTS

[0591] Constructs for ZC1, ZC2, ZC3, SULU1, SULU3, PAK4 and PAK5 have been generated.

[0592] Numerous additional constructs have been generated for the various STE20-subfamily kinases, including full length, kinase inactive and tagged versions. In addition, the following three constructs were designed for specific applications based on their unique domain structure:

Construct 1: SULU1-coiled-coil2

Vector: pGEX-4T

Insert: Coiled-coil2

Sequence: Amino acids 752-898

Purpose: phage display

Result: Interacts with GEK2 CC1

Construct 2: SULU3-coiled-coil2

Vector: pGEX4T

Insert: coiled-coil 2 domain fused to GST

Sequence range of insert: amino acids 802-898 of SEQ

Purpose: phage display

Result: Interacts with coiled-coiled region of human SLK

Construct 3: PAK5 Dominant Negative

Vector: pCAN5

Insert: Full length coding sequence of human PAK5 containing the following mutation:

K350,351A (Lys at aa positions 350 and 351 changed to Ala).

Purpose: to determine role of human PAK5 kinase activity in cell growth and transformation.

Result: Interferes with Ras transformation.

EXAMPLE 4: Generation of Specific Immunoreagents to STE20-Related Protein Kinases

Materials and Methods

[0593] Specific immunoreagents were raised in rabbits against KLH- or MAP-conjugated synthetic peptides corresponding to the human STE20-related kinases. C-terminal peptides were conjugated to KLH with glutaraldehyde, leaving a free C-terminus. Internal peptides were MAP-conjugated with a blocked N-terminus. Additional immunoreagents can also be generated by immunizing rabbits with the bacterially expressed GST-fusion proteins containing the cytoplasmic domains of each novel STK.

[0594] The various immune sera are first tested for reactivity and selectivity to recombinant protein, prior to testing for endogenous sources.

Western blots

[0595] Proteins in SDS PAGE are transferred to immobilon membrane. The washing buffer is PBST (standard phosphate-buffered saline pH 7.4 + 0.1% triton x 100). Blocking and antibody incubation buffer is PBST +5% milk. Antibody dilutions varied from 1:1000 to 1:2000.

RESULTS

[0596] Three SULU1 antisera (against both 539A (SEQ ID NO: 79) and 540A (SEQ ID NO: 78)) and two SULU3 antisera (542A) (SEQ ID NO: 81) reacted specifically with the peptide antigens. Antisera binding was competable with peptide. Experiments with extracts from cells transfected with epitope-tagged SULU1 and SULU3 genes are underway.

[0597] Antisera against the PAK4 C-terminal peptide 554A (SEQ ID NO: 82) reacted with purified Gst-PAK4 and detected a protein of the correct molecular weight from tissue culture cells. Specific immunoprecipitation experiments are ongoing to determine the reactivity with native protein.

[0598] Similar immunization and antisera testing experiments are underway for each of the other novel STE20-kinases.

STE20-related protein kinase peptide immunogens and their specificity in recognizing endogenous protein by Western blots or immunoprecipitations.

Protein	Sequence	Aa positions	Conj	West.	IP
STLK2	EKFQKCSADESP (SEQ ID No: 111)	405-416	KLH	Y	Y
STLK4	SISNSELFPTTDPVGT (SEQ ID NO: 112)	252-267	KLH	Y	Y
SULU1	LDFPKEDYR (SEQ ID NO: 113)	890-898	KLH	Y	Y
SULU1	HGDP RP EPRPTQ (SEQ ID NO: 114)	409-420	KLH	Y	Y
SULU3	PSTNRAGSLKDPEC (SEQ ID NO: 115)	2-14	KLH	N	ND
SULU3	DPRTRASDPQSPPQVSRH K (SEQ ID NO: 116)	411-429	KLH	ND	ND
PAK4	CLVPLIQLYRKQTSTC (SEQ ID NO: 117)	666-680	KLH	ND	Y
PAK5	PLMRQNRTR (SEQ ID NO: 118)	390-398	KLH	Y	Y
PAK5	SGDRRRAGPEKRPKSS (SEQ ID NO: 119)	148-163	KLH	Y	Y
PAK5	(C) RRKSLVGTPYWMAPE (SEQ ID NO: 120)	471-485	KLH	Y	ND

ND=not done yet

STE20-related protein kinase GST fusion protein immunogens and their specificity in recognizing endogenous protein by Western blots or immunoprecipitations.

Protein	domain	Aa positions	West.	IP
ZC1	Coiled-coil/pro/B/C	350-867	Y	Y
ZC1	B	615-732	Y	Y
ZC2	Coiled-coil /pro/B	348-762	ND	ND
ZC2	B	658-762	Y	Y
PAK4	Nterm	252-426	ND	ND
PAK4	Kinase/Cterm	350-681	ND	Y
PAK5	A/ Nterm	53-330	ND	ND
PAK5	A/Nterm	53-309	ND	ND

ND=not done yet

[0599] The 50kD STLK2 protein was expressed highly in several hematopoietic cell lines including Jurkat, pGL10, Ramos, A20, WEHI-231, K562, HEL and freshly isolated thymocytes from C57/BL6 mice. High levels of STLK2 expression were also detected in several tumor cell lines including Calu6, Colo205, LS180, MDAM231 and A549.

[0600] The 160 kD ZC1 protein was detected in Jurkat T cells, Colo205, HCT116, RIE-1, 293T, MDAMB231, and SK-MEL28.

[0601] The 170 kD ZC2 protein was detected in SK-Mel28 and UACC-62.

[0602] Elevated levels of the 64 kD PAK5 protein were confirmed in the breast cancer cell lines MDA-231 and MCF-7, and in the lung cancer cell line A549.

Example 5: Recombinant Expression and Biological Assays for STE20-related Protein Kinases

Materials and Methods

Transient Expression of the Ste20-related Kinases in Mammalian Cells

[0603] The pcDNA expression plasmids (10 µg DNA/100 mm plate) containing the STE20-related kinase constructs are introduced into 293 cells with lipofectamine (Gibco BRL). After 72 hours, the cells are harvested in 0.5 mL solubilization buffer (20 mM HEPES, pH 7.35, 150 mM NaCl, 10% glycerol, 1% Triton X-100, 1.5 mM MgCl₂, 1 mM EGTA, 2 mM phenylmethylsulfonyl fluoride, 1 µg/mL aprotinin). Sample aliquots were resolved by SDS polyacrylamide gel electrophoresis (PAGE) on 6% acrylamide/0.5% bis-acrylamide gels and electrophoretically transferred to nitrocellulose. Non-specific

binding was blocked by preincubating blots in Blotto (phosphate buffered saline containing 5% w/v non-fat dried milk and 0.2% v/v nonidet P-40 (Sigma)), and recombinant protein was detected using the various anti-peptide or anti-GST-fusion specific antisera.

In Vitro Kinase Assays

[0604] Three days after transfection with the STE20-related kinase expression constructs, a 10 cm plate of 293 cells was washed with PBS and solubilized on ice with 2 mL PBSTDS containing phosphatase inhibitors (10 mM NaHPO₄, pH 7.25, 150 mM NaCl, 1% Triton X-100, 0.5% deoxycholate, 0.1% SDS, 0.2% sodium azide, 1 mM NaF, 1 mM EGTA, 4 mM sodium orthovanadate, 1% aprotinin, 5 µg/mL leupeptin). Cell debris was removed by centrifugation (12000 x g, 15 min, 4 °C) and the lysate was precleared by two successive incubations with 50 µL of a 1:1 slurry of protein A sepharose for 1 hour each. One-half mL of the cleared supernatant was reacted with 10 µL of protein A purified kinase-specific antisera (generated from the GST fusion protein or antipeptide antisera) plus 50 µL of a 1:1 slurry of protein A-sepharose for 2 hr at 4 °C. The beads were then washed 2 times in PBSTDS, and 2 times in HNTG (20 mM HEPES, pH 7.5/150 mM NaCl, 0.1% Triton X-100, 10% glycerol).

[0605] The immunopurified kinases on sepharose beads were resuspended in 20 µL HNTG plus 30 mM MgCl₂, 10 mM MnCl₂, and 20 µCi [α ³²P]ATP (3000 Ci/mmol). The kinase reactions were run for 30 min at room temperature, and stopped by addition of HNTG supplemented with 50 mM EDTA. The samples were washed 6 times in HNTG, boiled 5 min in SDS sample buffer and analyzed by 6% SDS-PAGE followed by autoradiography. Phosphoamino acid analysis was performed by standard 2D methods on ³²P-labeled bands excised from the SDS-PAGE gel.

[0606] Similar assays were performed on bacterially expressed GST-fusion constructs of the kinases.

[0607] ZC1 Assay buffer: 20 mM Tris pH 7.4, 200 mM NaCl, 0.5 mM DTT, 3 mM MgCl₂, 0.3 mM MnCl₂, 100µM ³²P γ ATP.

[0608] Substrates: myelin basic protein (MBP) at 0.28 mg/mL and phosphorylated

ZC1 peptide RTVGRRNTFIG**T**-PPYWMAPE(SEQ ID NO:121) at 17 μ M (bold underlined residue shows site of phosphorylation).

[0609] At higher concentrations of MgCl_2 (3 mM), the activity of ZC1 (both full-length and recombinant kinase domain) is up to 10-fold greater towards exogenous substrate MBP. In contrast, the autophosphorylation and the phosphorylation of the activation loop peptide substrate are both inhibited. Mn^{++} does not inhibit the autophosphorylation and the peptide phosphorylation by the truncated kinase domain form. However, both the MBP phosphorylation, Mn^{++} -preferring activity AND the autophosphorylating, Mg^{++} -preferring activity are eliminated with mutation of the ATP-binding lysine in ZC1 (Lys54Ala) indicating that both activities are attributable to the ZC1 kinase domain.

[0610] SULU1 Assay buffer: This buffer is identical to that for ZC1, except for 5 mM MgCl_2 . Under these conditions, other STE20 family members (PAK4, ZC1) were inhibited for autophosphorylation and required reducing the [Mn] to <0.3 mM for an efficient autophosphorylation reaction.

[0611] Substrates: MBP, phosvitin, or α -casein at 0.28 mg/mL.

[0612] PAK4, PAK5 Assay Buffer: 20mM Hepes pH 7.2, 130 mM KCl, 10 mM MgCl_2 , 1 mM NaF, 20 mM B-glycerolphosphate, 0.5 mM DTT, 50 μ M ATP, 0.5 μ Ci $^{32}\text{P}\gamma\text{ATP}$.

[0613] Substrates: MBP at 0.28 mg/mL and peptide substrates derived from PAK5 activation loop at 2.5 μ M.

[0614] STLK2 Assay buffer: Similar to that described above, except for the inclusion of 5 mM MgCl_2 , 5 mM MnCl_2 and 5 μ Ci $^{32}\text{P}\gamma\text{ATP}$.

Transformation (PAK experiments)

[0615] Low-passage NIH3T3 fibroblasts displaying normal morphology (flat, non-refractile cellular morphology), as well as low rates of spontaneous transformation, were used in transformation assays. NIH3T3 cells were maintained in Dulbecco's modified

Eagle's medium supplemented with 10% (v/v) fetal calf serum, penicillin (100 U/mL) and streptomycin (100 U/mL) and kept in an humidified incubator at 37 °C and 5% CO₂.

[0616] Cells were transfected with DNA-lipid complexes. As per manufacturer instructions, lipofectamine was utilized to transfect NIH3T3 cells. All transfections were with equal amounts of plasmid DNA (DNA from the appropriate expression vector without insert was used to give equivalent amounts of DNA per transfection). 1 µg of activated allele of H-Ras was co-transfected with increasing amounts of various alleles of PAK5.

[0617] Foci were scored after 3 weeks by fixing 10 min in 10% methanol, 10% acetic acid for 10 min, followed by staining with 0.4% (w/v) crystal violet in 10% methanol for 10 min, and washing with deionized water and drying at room temperature.

Transfections, stimulations, and luciferase assays (ZC1 experiments)

[0618] Cells (10⁷) were transiently transfected by electroporation using a Gene Pulser (Bio-Rad Labs) with the setting of 960 _F and 250 V. 20-40 hours later, transfected cells (about 10⁵) were stimulated with various stimuli. After a 6-hour stimulation, cells were lysed, and luciferase activities were measured using the MicroLumatPlus (EG&G Berthold). (J. Exp. Med. 183:611-620, 1996, hereby incorporated by reference herein in its entirety including any drawings, tables, or figures.)

RESULTS

Protein expression and kinase activity of novel STE20-related protein kinases

Protein	Observed size (kD)	Predicted Size(kD)	In vitro Kinase activity	Endogenous Kinase activity
STLK2	50	46	y	y
STLK4	55	50	y	ND
ZC1	160	140	y	y
ZC2	170	150	y	y
KHS2	ND	101	ND	ND
SULU1	119	105	y	y
SULU3	140	115	ND	Y
PAK4	80	75	y	y
PAK5	64	64	y	y

ZC1: Regulation of kinase activity

[0619] ZC1 is constitutively active as a full-length kinase when expressed either *in vitro* (TNT rabbit reticulocyte system) or in NIH 3T3, 293T, or H1299 tissue culture cells. The endogenously expressed kinase is also active when immunoprecipitated from carcinoma cell lines.

ZC1 signaling Pathways

[0620] Using human leukemic T cell line Jurkat as a model system, the impact of cotransfected wild-type ZC1 on the activation of two reporter genes, RE/AP-luciferase and NFκB luciferase, was examined. RE/AP is a composite in the IL-2 gene promoter containing both a NFκB-like site and an AP-1 site.

[0621] Optimal activation of both RE/AP-luciferase and NFκB-luciferase reporter genes in Jurkat T cells requires signals generated from stimulation of both T cell receptor and the costimulator receptor CD28. Cotransfection of wild-type ZC1 with either the RE/AP-luciferase or the NFκB-luciferase reporter results in the activation of RE/AP or NFκB when costimulated with the anti-T cell receptor monoclonal antibody or the pharmacological reagents PMA and ionomycin that bypass proximal T cell receptor. No activation was seen when costimulated with an anti-CD28 monoclonal antibody.

[0622] These results suggest that wild-type ZC1, when overexpressed, was replacing a CD28-specific signal to activate RE/AP or NFκB. These results imply that ZC1 is involved in the CD28 signaling pathway. Since NFκB is one of the major pathways also activated by the pro-inflammatory cytokine TNF-α signaling, it is also likely that ZC1 may be a component in the TNF-α signaling pathways.

PAK5: Design of specific peptide substrates

[0623] To aid in the development of *in vitro* kinase assays for screening small molecule libraries to identify specific inhibitors, the search for specific peptide substrates for PAK5 was undertaken.

[0624] The rationale used to design such peptides is based on the hypothesis that upon binding activated small G protein, PAK5 undergoes a conformational change that results in derepression of its kinase activity followed by autophosphorylation on the

activation loop resulting in a fully active kinase. The site of autophosphorylation for related family members has been identified by biochemical and/or genetic means (e.g. Wu, C, et al. J.Biol.Chem 270:15984-15992 and Szczepanowska, et al. Proc.Natl.Acad.Sci 94, 8503-8508, 1997). Specific peptide substrates for PAK5 were designed from the sequence of the activation loop of this kinase.

[0625] An activation loop PAK5 peptide phosphorylated on the Thr residue of the TPY motif served as a high-affinity substrate for PAK5.

PAK5 activation loop peptides as kinase substrates

Peptide #	Kinase	Sequence	Aa	SEQ ID	Kinase	substrate
1	PAK5	(C)RRKSLVGTPYWMAPE	471-485	120	PAK5	yes
2	PAK5	(C)RRKSLVG <u>T</u> PYWMAPE	471-485	120	PAK5	yes
3	PAK5	(C)RRK <u>S</u> LVGTPYWMAPE	471-485	120	PAK5	no
4	KHS1	KRKSFIGTPYWMAPE	171-185	122	PAK5	yes
5	STLK2	KRN ^T TFVGTPFWMAPE	175-189	123	PAK5	poor
6	SULU1	PANSFVGTPYWMAPE	174-188	124	PAK5	poor
7	ZC1	RRNTFIGTPYWMAPE	184-198	125	PAK5	poor
8	ZC1	RRNTFIG <u>T</u> PYWMAPE	184-198	126	PAK5	poor
9	STLK4	RNKVRKTFVGTPCWM APE	66-83	127	PAK5	poor
10	PAK5	(C)RRKSLVG <u>T</u> PYWMAPE	471-485	120	PAK4	yes

Note: underlined/ bold residue was phosphorylated

Peptide #	Kinase	Notes
1	PAK5	Equally well as MBB
2	PAK5	High Km for PAK5 (1-10 μ M)
3	PAK5	S is the site of phosphorylation
4	KHS1	Similar to peptide 1
5	STLK2	
6	SULU1	
7	ZC1	
8	ZC1	Better than 7
9	STLK4	

10	PAK5	Same Km as phosph. by PAK5
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PAK5: Transformation

[0626] Transformation of low-passage NIH3T3 cells by ras in the presence or absence of various alleles of PAK5 showed that the dominant negative, kinase-dead allele of PAK5 was able to block ras transformation of NIH3T3 cells. Thus, PAK5 activity is required for ras transformation of NIH3T3 cells. Inhibition of PAK5 activity may have therapeutic value as an anti-proliferative agent for treating cancer.

PAK4 and PAK5: interaction with Cdc42

[0627] PAK 4 interacts with CDC42 small G-protein but not Rac, RhoA, or Ras as determined by co-transfection of recombinant genes and detection by kinase assays. PAK5 also interacts with Cdc42. Coding sequences of activated alleles of small G proteins (ras, Cdc42, Rac, Rho) tagged with a Myc epitope were transiently expressed in 293T cells, various alleles of 35S-labeled PAK5 tagged with HA epitope were expressed *in vitro* with the reticulocyte (TNT) system.

Example 6: Chromosomal Localization of Ste20-Related Protein Kinases
Materials And Methods

[0628] STE20 protein kinases STLK3, STLK4, ZC1, ZC2, ZC3, KHS2, SULU1, PAK4, and PAK5 were mapped using the GeneBridge 4 Radiation Hybrid Panel, RH02.05 (Research Genetics). The GeneBridge 4 Panel consists of 91 hybrid panel samples, in addition to one human positive control (HFL), and one hamster negative control (A23). The standard reaction conditions used to test and conduct PCR reactions using the GeneBridge 4 Panel are available from Research Genetics.

[0629] Oligonucleotide sequences (all 5' to 3') used for PCR mapping were:

STLK3: CTCCCATTTCTAGCAAAATCA(SEQ ID NO:128),
AGAGGCAGTATTGTCAGATGTA(SEQ ID NO:129)
STLK4: CCACACATGCGTATCTCTGTTG(SEQ ID NO:130),
TTGCTAGAATTACATCAGGTACA(SEQ ID NO:131)
ZC1: ATCCCTGGATCACACTGCTTCT(SEQ ID NO:132),
CAAGGTGTTCTTTGCCTCTGTT(SEQ ID NO:133)
ZC2: AGATGGACTGTACTGGGAGGG(SEQ ID NO:134),

AGAAGAGCACTTGGCACTTATC(SEQ ID NO:135)
 ZC3: CATCATGAACTGGTGACGGG(SEQ ID NO:136),
 CCAGTGAAATCAAACCAGTAAAA(SEQ ID NO:137)
 SULU1: CAAAACCTGGCCGTCTCTTCTATT(SEQ ID NO:138),
 ATTTGTGCTACTGGGATTCTGTG(SEQ ID NO:139)
 KHS2: GAATAGCGGTACCATGATAGAATA(SEQ ID NO:140),
 TACCAAAAAGAGCCAAAAGTGTG(SEQ ID NO:141)
 PAK4: CTCAGTATTCTCTCCAAAGATTG(SEQ ID NO:142),
 GATGTTCTCTCCATTCTGTAAAG(SEQ ID NO:143)
 PAK5: CATCACTGGAAGTCTGCAGTG(SEQ ID NO:144),
 CAGGTGCAGTAGTCATTTGC(SEQ ID NO:145)

[0630] Positive reactions were assigned a score of “1”, negative reactions are assigned a score of “0”, and ambiguous reactions are assigned a score of “2”. Results were submitted to the Whitehead Institute (www@genome.wi.mit.edu) for position analysis. Chromosomal localizations for ZC4, SULU3, STLK2, STLK5 and STLK6 were available publicly (for example, from Unigene). The chromosomal locations of GEK2 and STLK7 have not been determined.

STLK2_h	Xq25-27.1	(Public)
STLK3	2q31.3	(Sugen)
STLK4_h	3p22.3-p22.2	(Sugen)
STLK5_h	17q23.2-24.2	(Public)
STLK6_h	2q32.2-q33.3	(Public)
STLK7_h	NA	
ZC1_h	2p11.2	(Sugen)
ZC2_h	3q26.31-3q26.32	(Sugen)
ZC3_h	17p13.2-13.3	(Sugen)
ZC4_h	Xq22	(Public)
KHS2_h	2p22-2p22.2	(Sugen)
SULU1_h	12q24.21	(Sugen)
SULU3_h	17p11.2	(Public)
GEK2_h	NA	
PAK4_h	15q14	(Sugen)
PAK5_h	19q13.2-q13.3	(Sugen)

[0631] Many of the STE 20 kinases were mapped to regions associated with various human cancers, as shown below.

[0632] The regions were also cross-checked with the Mendelian Inheritance in

Man database, which tracks genetic information for many human diseases, including cancer. References for association of the mapped sites with chromosomal abnormalities found in human cancer can be found in: Knuutila, et al., Am J Pathol, 1998, 152:1107-1123, hereby incorporated herein by reference in its entirety including any figures, tables, or drawings. Association of these mapped regions with other diseases is documented in the Online Mendelian Inheritance in Man (OMIM).

STLK2_h, Xq25-27.1, (Public)

Osteosarcoma, Xq25-qter, 2 of 31.

Lymphoproliferative syndrome, X-linked (OMIM No. 308240)

human STLK3, 2q31.3, (Sugen)

Squamous cell carcinoma of Head and Neck, 3 of 30.

STLK4_h, 3p22.3-p22.2, (Sugen)

Mantle cell lymphoma 3p14-p22 1 of 27

Squamous cell carcinoma of Head and Neck 3p22-p24 1 of 14

Cardiomyopathy, dilated (OMIM 601154)

STLK5_h, 17q23.2-24.2, (Public)

Cervical cancer, 17q, 1 of 30

Gastroesophageal junction adenocarcinoma xenograft, 17q, 1 of 5

Breast carcinoma, 17q12-qter, 1 of 16

Bladder carcinoma, 17q22-q23, 1 of 14

Breast carcinoma, 17q22-q25, 8 of 101

Non-small cell lung cancer, 17q24-q25, 6 of 50

Testis, 17q24-qter, 2 of 11

Malignant peripheral nerve sheath tumors, 17q24-qter, 5 of 7

Alzheimer disease, susceptibility to (OMIM 106180)

STLK6_h, 2q32.2 –q33.3, (Public)

Non-small cell lung cancer, 2q31-q32, 1 of 50

Squamous cell carcinoma of Head and Neck, 2q31-q33, 3 of 30

Small cell lung cancer, 2q32-q35, 1 of 22

ZC1_h, 2p11.2, (Sugen)

non-small cell lung cancer, 2pter-q13, 1 of 10

non-small cell lung cancer, 2pter-q21, 1 of 10

Pulmonary alveolar proteinosis, congenital (OMIM 178640).

ZC2_h, 3q26.31-3q26.32, (Sugen)

Non-small cell lung cancer, 3q26.1-q26.3, 26 of 103

Cervical cancer, 3q26.1-q27, 4 of 30

Small cell lung cancer, 3q26.3-qter, 3 of 35

Squamous cell carcinoma of Head and Neck, 3q26.3-qter, 3 of 13

Marginal zone B-cell lymphoma, 3q26-q27, 1 of 25

Parosteal osteosarcoma, 3q26-q28, 1 of 1

Gastrointestinal stromal tumor, 3q26-q29, 1 of 16

Mantle cell lymphoma, 3q26-q29, 1 of 5

ZC3_h 17p13.2-13.3 (Sugen)

Malignant fibrous histiocytoma of soft tissue, 17p, 2 of 58

Leiomyosarcoma, 17p, 7 of 29

Non-small cell lung cancer, 17p, 1 of 50

ZC4_h, Xq22, (Public)

Diffuse large cell lymphoma, Xq22-ter, 1 of 32

Deafness, X-linked 1, progressive. (OMIM 304700).

KHS2_h, 2p22-2p22.2, (Sugen)

Synovial sarcoma, 2p21-q14, 1_of_67

Follicular lymphoma, 2p22-p24, 1_of_46

Colorectal cancer, hereditary, nonpolyposis, type 1, Ovarian cancer (MSH2, COCA1,

FCC1). (OMIM 120435).

SULU1_h, 12q24.21 (Sugen)

Neuroglial tumors, 12q22-qter, 1_of_15

Gastroesophageal junction adenocarcinoma, 12q23-qter, 1 of 5.

Non-small cell lung cancer, 12q24.1-24.3, 2 of 50.

SULU3_h 17p11.2 (Public)

Malignant fibrous histiocytoma of soft tissue, 17p, 2_of_58

Leiomyosarcoma, 17p, 7_of_29

non-small cell lung cancer, 17p, 1_of_50

Diffuse large cell lymphoma, 17p11.2, 1_of_32

Osteosarcoma, 17p11.2-p12, 4_of_31

PAK4_h: 15q14 (Sugen)

Schizophrenia, (OMIM 118511).

PAK5_h: 19q13.2-q13.3 (Sugen)

Follicular lymphoma, 19q13, 1 of 46*

Mantle cell lymphoma, 19q13, 1 of 5

Hepatocellular carcinoma, 19q13.1, 2 of 50

Small cell lung cancer, 19q13.1, 10 of 35

Breast carcinoma, 19q13.1-qter, 1 of 33

cervical cancer, 19q13.1-qter, 1 of 30

Testis, 19q13.1-qter, 1 of 11

Chondrosarcoma, 19q13.2, 1 of 29

Malignant fibrous histiocytoma of soft tissue, 19q13.2-qter, 2 of 58

Non-small cell lung cancer, 19qcen-q13.3, 6 of 104

Example 7: Demonstration Of Gene Amplification By Southern Blotting
Materials and Methods

[0633] Nylon membranes were purchased from Boehringer Mannheim. Denaturing solution contains 0.4 M NaOH and 0.6 M NaCl. Neutralization solution contains 0.5 M Tris-HCL, pH 7.5 and 1.5 M NaCl. Hybridization solution contains 50% formamide, 6X SSPE, 2.5X Denhardt's solution, 0.2 mg/mL denatured salmon DNA, 0.1 mg/mL yeast tRNA, and 0.2 % sodium dodecyl sulfate. Restriction enzymes were purchased from Boehringer Mannheim. Radiolabeled probes were prepared using the Prime-it II kit by Stratagene. The beta actin DNA fragment used for a probe template was purchased from Clontech.

[0634] Genomic DNA was isolated from 20 different tumor cell lines: MCF-7, MDA-MB-231, Calu-6, A549, HCT-15, HT-29, Colo 205, LS-180, DLD-1, HCT-116, PC3, CAPAN-2, MIA-PaCa-2, PANC-1, AsPc-1, BxPC-3, OVCAR-3, SKOV3, SW 626 and PA-1, and from two normal cell lines: human mammary epithelial cells and human umbilical vein endothelial cells.

[0635] A 10 µg aliquot of each genomic DNA sample was digested with EcoR I restriction enzyme and a separate 10 µg sample was digested with Hind III restriction enzyme. The restriction-digested DNA samples were loaded onto a 0.7% agarose gel and, following electrophoretic separation, the DNA was capillary-transferred to a nylon membrane by standard methods (Sambrook, J. et al (1989) Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory).

PAK5 Amplicon:

[0636] A 600 base pair fragment (EcoR I - Sac I) of the PAK5 gene was used as a template for a radiolabeled DNA probe which was hybridized to the blots at 42 °C for 48 hours in hybridization solution using standard methods (supra). The blots were exposed to a phosphorimager screen for 4 days, then scanned and analyzed using a Molecular Dynamics Storm 840 phosphorimager. The relative mass and gene copy number values of the PAK5 DNA fragments were calculated from the band density values obtained. The blots were re-hybridized with a radiolabeled probe copied from a fragment of human beta actin DNA and developed as above to confirm the sample mass loading equivalency.

RESULTS

[0637] The PAK5 gene was determined to exhibit 3-fold amplification compared to the normal DNA copy number in PANC-1 (pancreatic epithelioid carcinoma) and OVCAR-3 (ovarian adenocarcinoma) human cell lines, and approximately 2 times the normal copy number in the BxPC-3 (primary pancreatic adenocarcinoma) human cell line.

[0638] Similar Southern analyses can be performed for other STE20 kinases.

Example 8: Detection Of Protein-Protein Interaction
Through Phage Display

Materials And Methods

[0639] Phage display provides a method for isolating molecular interactions based on affinity for a desired bait. cDNA fragments cloned as fusions to phage coat proteins are displayed on the surface of the phage. Phage(s) interacting with a bait are enriched by affinity purification and the insert DNA from individual clones is analyzed.

T7 Phage Display Libraries

[0640] All libraries were constructed in the T7Select1-1b vector (Novagen) according to the manufacturer's directions.

Bait Presentation

[0641] Protein domains to be used as baits were generated as C-terminal fusions to GST and expressed in *E. coli*. Peptides were chemically synthesized and biotinylated at the N-terminus using a long chain spacer biotin reagent.

Selection

[0642] Aliquots of refreshed libraries (10^{10} - 10^{12} pfu) supplemented with PanMix and a cocktail of *E. coli* inhibitors (Sigma P-8465) were incubated for 1-2 hrs at room temperature with the immobilized baits. Unbound phage was extensively washed (at least 4 times) with wash buffer.

[0643] After 3-4 rounds of selection, bound phage was eluted in 100 μ L of 1% SDS and plated on agarose plates to obtain single plaques.

Identification of insert DNAs

[0644] Individual plaques were picked into 25 μ L of 10 mM EDTA and the phage was disrupted by heating at 70 °C for 10 min. 2 μ L of the disrupted phage were added to 50 μ L PCR reaction mix. The insert DNA was amplified by 35 rounds of thermal cycling (94oC, 50sec; 50oC, 1min; 72oC, 1min).

Composition of Buffer

10x PanMix
5% Triton X100
10% non-fat dry milk (Carnation)
10 mM EGTA
250 mM NaF
250 μ g/mL Heparin (sigma)
250 μ g/mL sheared, boiled salmon sperm DNA (sigma)
0.05% Na azide
Prepared in PBS

Wash Buffer

PBS supplemented with:
0.5% NP-40
25 μ l g/mL heparin

PCR reaction mix

1.0 mL 10x PCR buffer (Perkin-Elmer, with 15 mM Mg)
0.2 mL each dNTPs (10 mM stock)
0.1 mL T7UP primer (15 pmol/ μ L) GGAGCTGTCGTATTCCAGTC
0.1 mL T7DN primer (15 pmol/ μ L) AACCCCTCAAGACCCGTTTAG
0.2 mL 25 mM MgCl₂ or MgSO₄ to compensate for EDTA
Q.S. to 10 mL with distilled water
Add 1 unit of Taq polymerase per 50 μ L reaction

PCR reaction mix

1.0 mL 10x PCR buffer (Perkin-Elmer, with 15 mM Mg)
 0.2 mL each dNTPs (10 mM stock)
 0.1 mL T7UP primer (15 pmol/μL) GGAGCTGTCGTATTCCAGTC(SEQ ID NO:146)
 0.1 mL T7DN primer (15 pmol/μL) AACCCCTCAAGACCCGTTTAG(SEQ ID NO:147)
 0.2 mL 25 mM MgCl₂ or MgSO₄ to compensate for EDTA
 Q.S. to 10 mL with distilled water
 Add 1 unit of Taq polymerase per 50 μL reaction

LIBRARY: T7 Select1-H441

RESULTS

Phage display baits and interactors

Bait	Domain	Aa	Patent SEQ ID	CDNA library	Interactor	Sequence Range & SEQ ID
SULU1	Coiled-coil2	752-898	22	H441	GEK2 cc dom (1)	677-820 SEQ #26
SULU3	Coiled-coil2	755-898	23	H441	SLK isoform	M83780

SULU1 cc1 also interacted to a lesser extent with the coiled-coil domain of an SLK isoform.

[0645] The phage display data suggest potential interactions of SULU3 with SLK and SULU1 with GEK2 through their coiled-coil domains. Therefore two members of the SULU subfamily of STE20 kinases interact with two members of a separate STE20 family, the prototype being SLK.

[0646] These results suggest a specificity in the interaction, and imply that these STE20 kinases may interact with each other through homo- and hetero-dimerization. Alternatively SULU-related kinases could act immediately up- or down-stream of the SLK-related kinases in a signaling cascade.

[0647] One skilled in the art would readily appreciate that the present invention is well adapted to carry out the objects and obtain the ends and advantages mentioned, as well as those inherent therein. The molecular complexes and the methods, procedures, treatments, molecules, specific compounds described herein are presently representative of

preferred embodiments are exemplary and are not intended as limitations on the scope of the invention. Changes therein and other uses will occur to those skilled in the art which are encompassed within the spirit of the invention are defined by the scope of the claims.

[0648] It will be readily apparent to one skilled in the art that varying substitutions and modifications may be made to the invention disclosed herein without departing from the scope and spirit of the invention.

[0649] All patents and publications mentioned in the specification are indicative of the levels of those skilled in the art to which the invention pertains.

[0650] The invention illustratively described herein suitably may be practiced in the absence of any element or elements, limitation or limitations which is not specifically disclosed herein. Thus, for example, in each instance herein any of the terms “comprising”, “consisting essentially of” and “consisting of” may be replaced with either of the other two terms. The terms and expressions which have been employed are used as terms of description and not of limitation, and there is no intention that in the use of such terms and expressions of excluding any equivalents of the features shown and described or portions thereof, but it is recognized that various modifications are possible within the scope of the invention claimed.

[0651] In particular, although some formulations described herein have been identified by the excipients added to the formulations, the invention is meant to also cover the final formulation formed by the combination of these excipients. Specifically, the invention includes formulations in which one to all of the added excipients undergo a reaction during formulation and are no longer present in the final formulation, or are present in modified forms.

[0652] In addition, where features or aspects of the invention are described in terms of Markush groups, those skilled in the art will recognize that the invention is also thereby described in terms of any individual member or subgroup of members of the Markush group. For example, if X is described as selected from the group consisting of bromine, chlorine, and iodine, claims for X being bromine and claims for X being bromine and chlorine are fully described.

[0653] Other embodiments are within the following claims.